Aeration Control Using Continuous Dissolved Oxygen Monitoring to Reduce Energy Demands in Activated Sludge Wastewater Treatment Systems

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Given their intensive energy demands, wastewater treatment plants provide many high-return opportunities for energy conservation projects. Even well-designed, relatively new wastewater treatment facilities can often be enhanced to significantly decrease energy use. Several innovative ideas to reduce energy consumption have recently been applied at the UC Davis Wastewater Treatment Plant (WWTP), which became operational in 2000.

The UC Davis WWTP has an annual average design capacity of 2.5 million gallons per day (Mgd) and provides wastewater treatment for the 3,600-acre main campus. Treatment processes include a three-channel oxidation ditch, clarifiers, sand filter cells, and ultraviolet light (UV) disinfection. Solids handling processes for waste activated sludge include solids storage basins (SSB) and solids drying beds. Thus, the UC Davis WWTP is similar to many small municipal wastewater treatment plants currently in use in California and across the United States. Moreover, tertiary treatment plant designs of this type are becoming increasingly common as wastewater permits and environmental regulations become more stringent.

Following commissioning, the University evaluated the WWTP and identified two major design changes predicted to reduce energy consumption. The first concept was to establish a dissolved oxygen (DO) feedback loop to control variable frequency drives (VFDs) on the motors used to aerate the oxidation ditches. The second concept was to establish an automated means to provide greater turndown for the UV disinfection system during low-flow conditions. These plant modifications were subsequently designed and implemented by UC Davis in partnership with the California Department of Water Resources (DWR), funded under DWR Contract 4600002347. This report describes and evaluates the oxidation ditch control project.

The process control changes necessary to automate oxidation ditch aeration at the UC Davis WWTP were relatively easy to implement and our data indicates that the project has significantly reduced energy use while maintaining or improving effluent water quality.

After twelve months of operation, our principal conclusions are as follows:

- The availability of a debris-free, low-maintenance, in-line DO meter is an important innovation that makes automatic DO loop control operationally practical for activated sludge treatment systems. The tested DO monitoring system has proven to be extremely reliable with very little maintenance required. The automated control system has consistently maintained set-point DO levels in the oxidation ditch without discernable drift or error.

- The use of VFDs for oxidation ditch aeration in conjunction with DO feedback-loop control has reduced WWTP electrical consumption by an average of 23% or 755 kilowatt-hours per million gallons (kWh/Mg) (Figure 9). The project was found to have a 1.2 year payback at the prevailing municipal electrical rate of $0.09/kWh.

- Beyond energy efficiency, the ability to maintain DO at prescribed levels in the oxidation ditch has afforded operators a higher degree of biological process control. Effluent quality has improved as a result. The sludge volume index (SVI) increased from an average of 84 to 99. Ammonia as nitrogen has consistently remained below 0.5 mg/L after implementation.

- The revised system was designed to consistently maintain DO at fixed levels with the goal of maintaining a stable biological treatment process. However, other control strategies that vary DO levels over time are also possible. Use of variable DO control strategies might allow for a further reduction in energy consumption or enhanced biological treatment. These concepts are recommended for future study.

These findings have broad application. Given the large number of operationally similar wastewater treatment facilities, the adoption of automatic DO controlled aeration at existing facilities could result in a significant cumulative decrease in current energy consumption. Additionally, future increases in energy demands from new WWTP could be lessened if design engineers adopt these concepts.

1.1 Plant Description

The UC Davis wastewater treatment plant (WWTP), designed by Brown and Caldwell, was commissioned in March of 2000. Prior to that, wastewater from the campus was treated at a treatment plant that was constructed in 1949 and upgraded in 1970 and 1988. The University elected to construct a new WWTP when the old plant was facing tighter discharge requirements and reaching the end of its useful life.

The new plant schematic is provided in Figure 1. Wastewater generated by the campus continues to flow to the old WWTP site and is then pumped to the new WWTP. The treatment plant was designed for an average-day flow of 2.5 million gallon per day (Mgd) and a peak hourly flow of 6.3 Mgd. Wastewater treatment processes include an oxidation ditch, clarifiers, sand filter cells, and ultraviolet light (UV) disinfection. Treated effluent is discharged to the South Fork of Putah Creek. Solids handling processes for waste activated sludge include solids storage basins (SSB) and solids drying beds. The dried solids are transported offsite for landfill disposal. Table 1 summarizes the treatment processes.

Table 1. Unit Processes at the UC Davis WWTP

Process	Description
Headworks	2 Channel Monsters® and 1 Auger Monster™
Oxidation Ditch	3 channels (Orbal by U.S. Filter/Envirex Inc.)
Clarifiers	2 clarifiers
Filters	3 filters (Hydro-Clear®)
UV Disinfection	2 channels (Trojan 3000)
Solids Storage Basins (SSBs)	2 basins
Solids Drying Beds	2 beds

1.2 Discharge Requirements

The UC Davis WWTP operates within an extremely strict discharge permit issued by the Central Valley Regional Water Quality Control Board under the National Pollutant Discharge Elimination System (NPDES). Tables 2 and 3 list key effluent limits. The permit requires the treated wastewater to meet California's "Title 22" water reclamation criteria. The plant has been producing high quality effluent since its commissioning.

Figure 1-1. Wastewater Treatment Plant Schematic

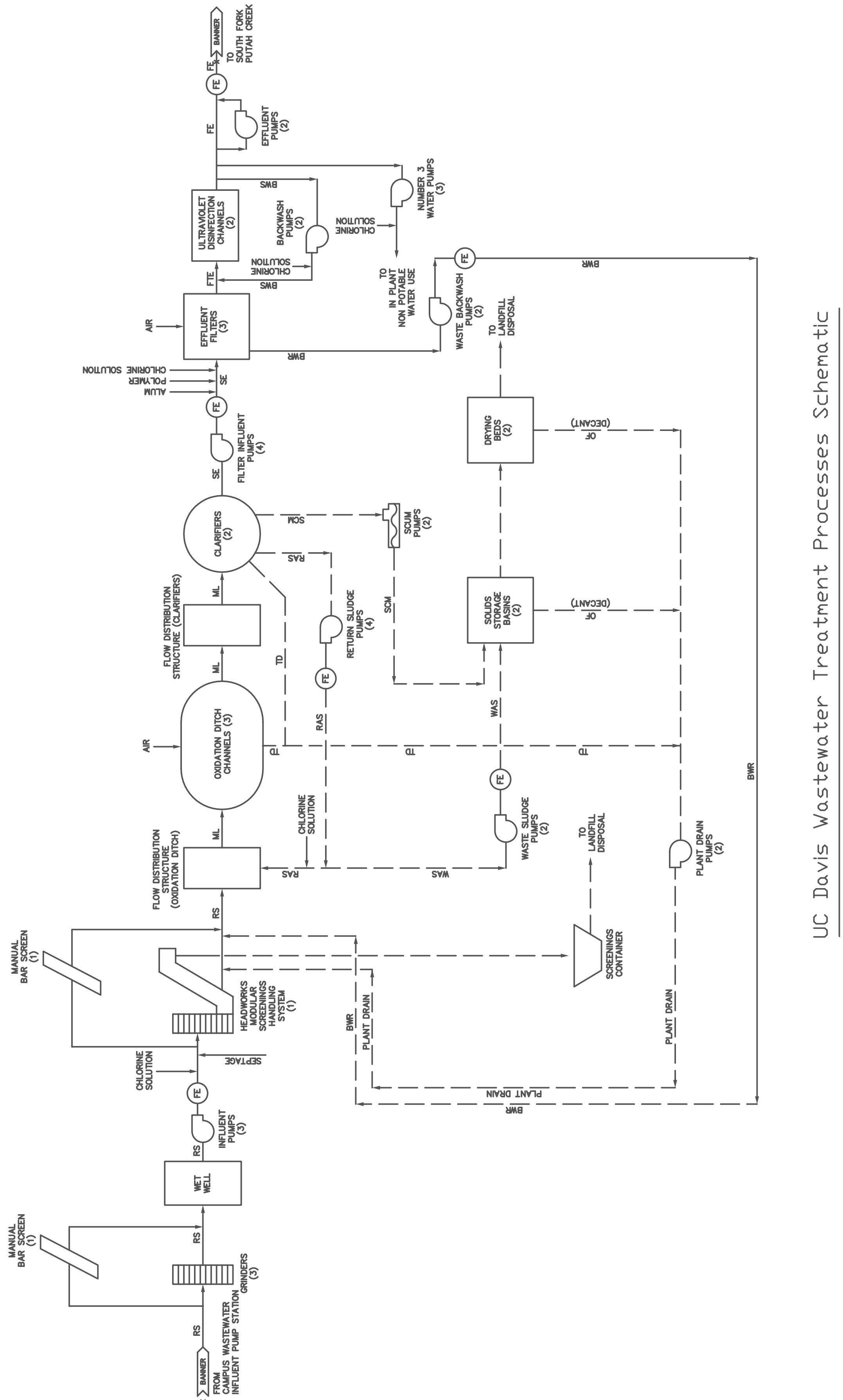


Table 1-2. NPDES Permit Effluent Limits for Conventional Pollutants

Constituents	Units	Monthly Average	Weekly Average	7-Day Median	Daily Average	Daily Maximum
BOD	mg/L	10**	15**	---	---	25**
	lb/day***	225	338	---	---	560
Total Suspended Solids	mg/L	10**	15**	---	---	25**
	lb/day***	225	338	---	---	560
Total Coliform Organisms	MPN/ 100ml	---	---	2.2	---	23
Settleable Solids	Ml/l	---	---	---	---	0.1
Turbidity	NTU	---	---	---	2	5*

*) The turbidity shall not exceed 5 NTU more than 5 percent of the time within a 24-hour period. At no time shall the turbidity exceed 10 NTU.
**) To be ascertained by a 24- hour composite.
***) Based upon a permit dry-weather treatment capacity of 2.7 Mgd

Table 1-3. Additional NPDES Effluent Permit Limits

Constituents	Units	Monthly Average	4-Day Average	Daily Average	1-Hour Average
Total Residual Chlorine	mg/L	---	0.01	---	0.02
	lbs/day***	----	0.225	---	0.45
Ammonia (as N)	mg/L	pH based	---	---	pH based
	lbs/day***	---	---	---	---
Nitrate + Nitrite (as N)	mg/L	10	---	---	---
	lbs/day***	225	---	---	---
Aluminum	µg/*l*	---	87	---	750
	lbs/day***	---	1.9	---	16.8
Cyanide	µg/*l*	---	5.2	---	22
	lbs/day***	---	0.113	---	0.5
Copper	µg/*l*		Hardness based	---	---
	lbs/day***		---	---	---
Dichloromethane	µg/*l*	4.7	---	---	---
	lbs/day***	0.1	---	---	---
Dioxin/Furans	pg/ *l*	0.014	---	---	---
	lbs/day***	0	---	---	---
Iron	µg/*l*	300	---	---	---
	lbs/day***	6.8	---	---	---

***) Based upon a permit dry-weather treatment capacity of 2.7 Mgd

1.3 Electrical Use and Costs

During its first two years of operation, the UC Davis WWTP used an average of nearly 2,000,0000 kWh per year. UC Davis' average electricity cost is relatively low at $0.054/kWh. Nonetheless, power costs for the WWTP account for nearly 10% of the $1.1 million total annual cost to operate and maintain the plant.

1.4 Identification of Energy Reduction Opportunities

Following commissioning of the new plant, each of the major treatment processes was reviewed to identify potential energy reduction projects. Results from this survey are discussed below.

Headworks

Wastewater passes through a manual bar screen, and is then routed to two influent channels prior to entering the influent pump station. There are two "Channel Monster®" grinders installed in one of the channels. The two grinders were designed to run continuously, but we found that using the existing PLC to turn off one of the grinders during low flow periods reduced energy use without any adverse impacts. This design change was subsequently implemented during a previous project.

Oxidation Ditch

A 260 horsepower (hp) aeration system is installed in the three-ring oxidation ditch system. Under the original design, the amount of air supplied to the ditches is manually controlled based on the dissolved oxygen (DO) level. For optimal treatment, the manufacturer of the oxidation ditch (U.S. Filter/Envirex Inc.) recommends that the aerobic zone be maintained at a constant DO level of 2.0 mg/L. A DO level of less than 0.5 mg/L is recommended for the anoxic zone. Though the original design featured eight 2-speed motors capable of running both forward and reverse, for a total of five different aeration settings for each motor, it was difficult to operate the system close to the actual oxygen demand without over-aerating the wastewater. Over-aeration wastes energy and can cause undesirable changes in the biological characteristics of the wastewater. Replacing some of the existing two-speed motors with VFDs was identified as a means to reduce energy consumption. The installation of a reliable, continuously-monitoring DO device coupled with a feedback control loop to the VFDs would fully automate this improvement. These changes were subsequently designed and implemented by UC Davis in cooperation with the DWR, funded under DWR Contract 4600002347, and are the focus of this report.

Filter Influent Pump Station

The influent pump station consists of four 40-hp vertical turbine open line shaft pumps. All four pumps are operated under VFD. Partially treated water is pumped from the wetwell to the filter for further treatment. The survey identified that water levels could be maintained at a level 1.5' higher than the original setting. Implementing this change reduced the static head for the pump to pump water by 1.5' with the resultant reduction in energy consumption. This design change was immediately implemented.

UV Disinfection

The treatment plant uses UV light to disinfect the treated water. Ultraviolet disinfection has several advantages over traditional chlorine disinfection, most notably the elimination of safety concerns associated with accidental chemical releases and lack of chlorine disinfection by-products in the treated effluent. However, UV disinfection uses significantly more energy. Under the original design for UC Davis, the UV system accounts for 20% of the total electricity used by the plant. The design includes two channels, each with four banks of UV modules. A minimum of two UV banks must remain on when a channel is in use. The system was designed to keep both channels in operation except during maintenance. Thus, at least four UV banks are always on. When flows increase, the third banks in each channel are automatically turned on. The fourth banks in each channel are kept in reserve to provide back-up for any of the three operational banks. Given this design, UV power consumption is always fixed at either 67% or 100% of maximum consumption. A process control change to automatically divert all flow to one of the channels during low-flow periods would allow for a greater turn-down of UV power consumption. The revised system would be able to run at 33%, 50%, 67%, and 100% of maximum power. Information from the UV Design Guidelines (NWRI, December, 2000) affirm that the system could be modified as described and still maintain compliance with all permitted discharge limits. These changes were subsequently designed and implemented by UC Davis in cooperation with the DWR, funded under DWR Contract 4600002347, and are discussed in a separate report.

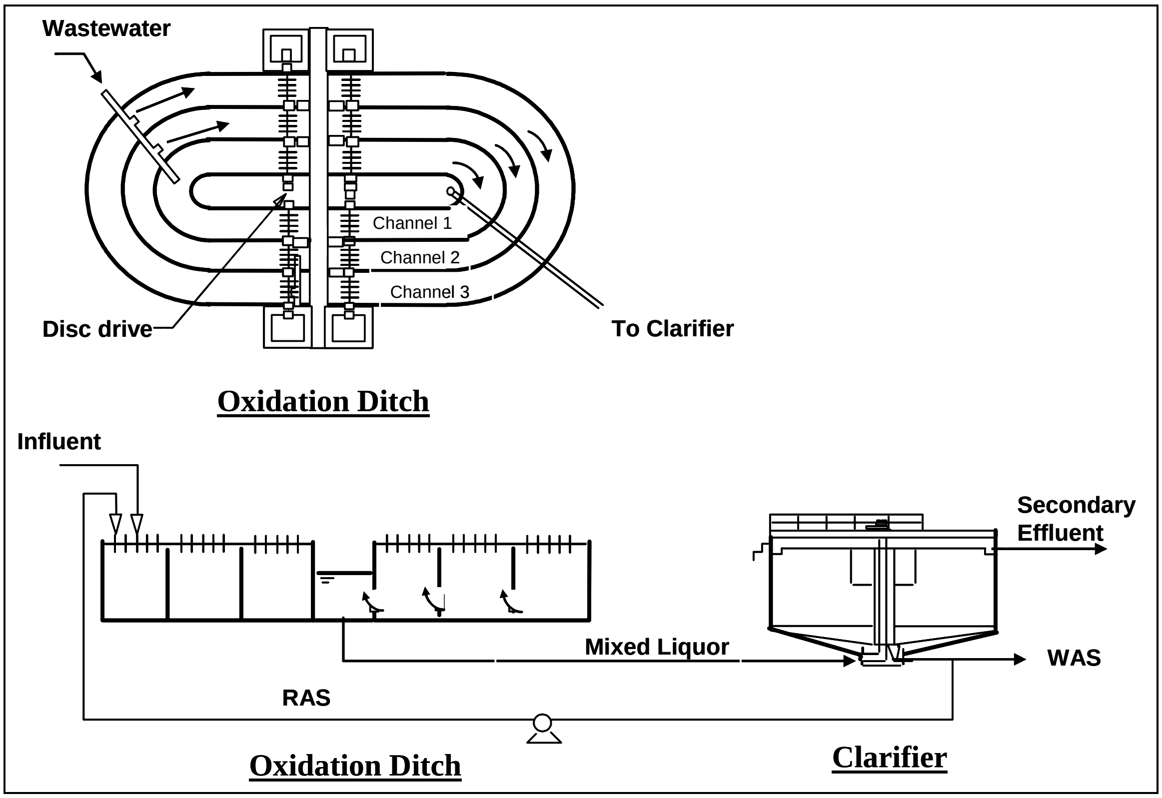
Solids Processing

The plant uses facultative ponds to digest its activated sludge. The water in each pond is circulated and aerated (within the surface layer) by two10-hp mixers. The survey found that one mixer could be turned off during the night and restarted the next morning without adversely affecting sludge treatment. This change was immediately implemented.

2.1 Original Oxidation Ditch Process Control

Oxidation ditches use an extended aeration biological treatment process to treat wastewater. The UC Davis WWTP has a three-channel U.S. Filter Envirex Orbal oxidation ditch. The design hydraulic detention time is 20.7 hours with a 20-day sludge age. Mixed liquor (MLSS) is maintained at 2,500 mg/L and 3,200 mg/L for returned activated sludge (RAS). The Orbal ditch is a single-sludge activated process with a series of three concentric looped reactors. Wastewater passes through the channels from the outermost channel, to the middle channel, and on to the innermost channel. Flow circulates around each of the three channels, allowing the raw sewage to be quickly dispersed with microorganism flocs. Figure 2 shows the ditch configuration.

Figure 2. Orbal Ditch and Clarifier Configuration



Aeration (oxygen transfer) in the Orbal system is provided by 4.5-foot-diameter plastic aeration disks. These discs also provide mixed liquor recirculation within each channel to keep settleable solids in suspension. Water depth in the ditch is controlled by adjusting overflow weir height, which then changes the immersion of the disks. The amount of oxygen delivered is a function of immersion and disc speed. Power consumption increases with increased disk immersion and disc speed.

The outer channel has 50 percent of the total aeration basin volume and receives raw wastewater and RAS. The outer channel is operated at near-zero DO to create an anoxic condition where denitrification occurs. To ensure an anoxic condition is maintained in the outer channel, a minimum number of aerators must be operated to keep the oxygen supply at about 50% of the oxygen demand.

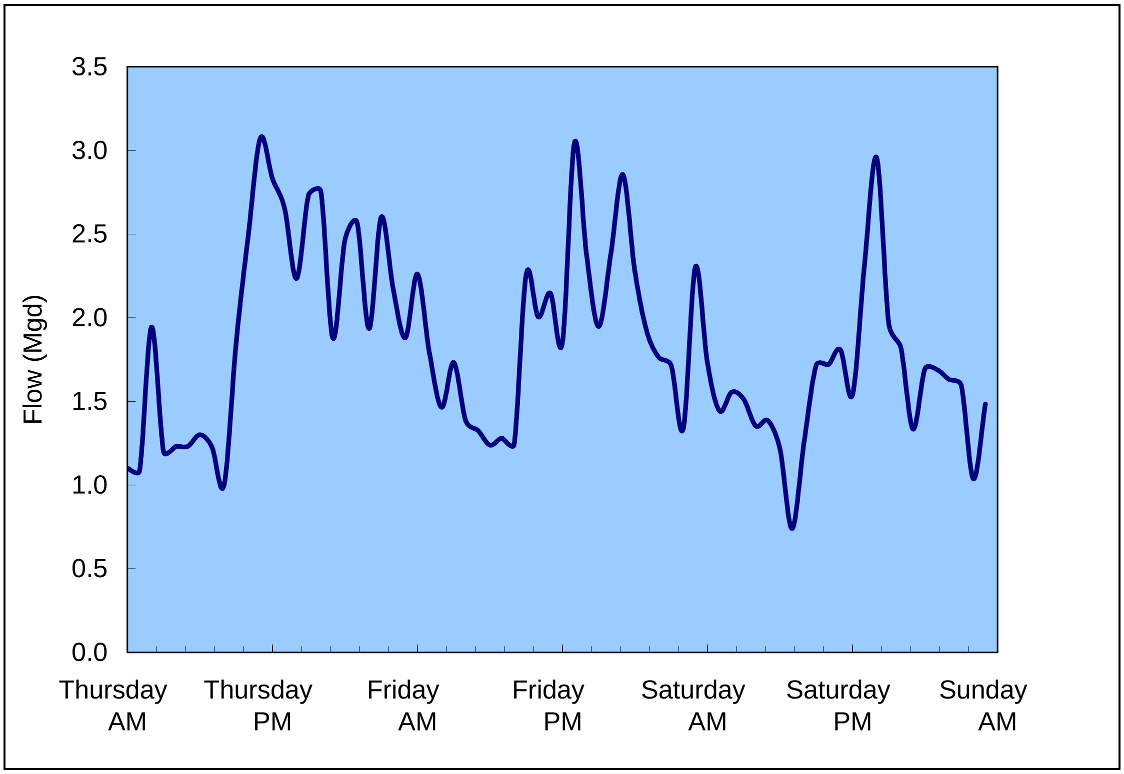
The ditch contains eight aerators: four with 40-hp motors and four with 25-hp motors. Each aerator is reversible, and capable of two speeds. There are a total of 264 discs mounted on the aerator shafts; 100 discs are installed in the outer channel, 96 discs in the middle channel, and 68 discs in the innermost channel. Discs in the innermost channel and the middle channel share a common shaft, connected by a mechanical coupler located between the two channels. The discs are designed with raised nodules shaped such that when rotated in a “Base Forward” direction they entrain a greater amount of air to the mixed liquor than when rotated in the opposite direction, “Apex Forward.” Rotation in the Base Forward position requires an increase in power draw and cause a corresponding increase in oxygen delivery. Performance characteristics of the discs in a typical Orbal channel with a velocity of 1.0 foot per second (fps) are shown in Table 4.

Table 4. Disc Oxygen Transfer and Power Consumption (per disc)

	Base Forward		**Apex Forward**	
	LBS. O_2/HOUR	**BHP**	**LBS. O_2/HOUR**	**BHP**
43 RPM				
21" immersion	1.66	0.48	1.25	0.36
19" immersion	1.54	0.44	1.14	0.33
17" immersion	1.38	0.4	1.04	0.30
15" immersion	1.25	0.36	0.94	0.27
13" immersion	1.11	0.32	0.84	0.24
11" immersion	0.98	0.28	0.74	0.21
9" immersion	0.85	0.24	0.64	0.18
55 RPM				
21" immersion	2.5	0.83	1.85	0.58
19" immersion	2.28	0.73	1.68	0.53
17" immersion	2.08	0.69	1.54	0.48
15" immersion	1.88	0.62	1.39	0.44
13" immersion	1.66	0.56	1.24	0.39
11" immersion	1.48	0.49	1.09	0.34
9" immersion	1.23	0.42	0.94	0.3

As originally designed and installed, aeration control in the oxidation ditch consisted of bringing aerators on and off line, setting aerator speeds either high or low, and adjusting the height of the effluent weirs. This system offers infinite flexibility to establish a given aeration rate within the required operational ranges; however, all control functions were to be executed manually by plant operations staff. In theory, an operator could make adjustments in aerator speed, rotation direction and weir height in an attempt to match the variation in flow, BOD, and ammonia. In practice, though, disc speed and rotation provided the primary means of control since these changes could be quickly made in comparison to changing immersion. Shortly after startup in 2000, it became clear that aeration with only two speed and two rotation directions was insufficient to closely respond to changes in diurnal flow and influent characteristics. Figure 3 shows the flow variation in a typical week for the plant. The flow starts to increase at 8:00 AM and tails off at around 1:00 AM the next day, with an average flow for that period of 2.5 Mgd. From 1:00 AM to 8:00 AM the average flow is only1.2 Mgd. The wastewater strength drops from a BOD_5 of 170 mg/L during the high flow period to 80 mg/L during the low flow period.

Figure 3. Typical hourly flows at UC Davis WWTP



Theoretical oxygen demand can be calculated given flow and wastewater strength. The oxygen demand varies throughout the day in response to variations in flow and wastewater strength. The calculations below illustrate the difficulty of manually adjusting aeration to match variable oxygen demands.

1) Under the typical high flow time period, the influent BOD_5 concentration is 170 mg/L and ammonia concentration is 15 mg/L, thus:

$$Pounds\ of\ BOD_5\ loading\ per\ hour =$$

$$\frac{2.5\ Mgd \times 170\ mg/L \times 8.34\ (l/Mg)(lb/mg)}{24\,hrs} = 148\ lbs/hr$$

$$Pounds\ of\ NH_3\ loading\ per\ hour =$$
$$\frac{2.5\ Mgd \times 15\ mg/L \times 8.34\ (l/Mg)(lb/mg)}{24\ hrs} = 13.0\ lbs/hr$$

$$Pounds\ of\ total\ O_2\ demand\ per\ hour =$$
$$148 lbs\ BOD_5/hr \times 1.2\ O_2 lbs/lbBOD_5 + 13.0 lbsNH_3/hr \times 4.6\ O_2/lbsNH_3$$
$$= 237\ lbs\ O_2/hr$$

2) Under the typical low flow period, the BOD_5 concentration is 80 mg/L and ammonia concentration is 5 mg/L, thus:

$$Pounds\ of\ BOD_5\ loading\ per\ hour =$$
$$\frac{1.2\ Mgd \times 80\ mg/L \times 8.34\ (l/Mg)(lb/mg)}{24 hrs} = 33.4\ lbs/hr$$

$$Pounds\ of\ NH_3\ loading\ per\ hour =$$
$$\frac{1.2\ Mgd \times 5\ mg/L \times 8.34\ (l/Mg)(lb/mg)}{24 hrs} = 2.09\ lbs/hr$$

$$Pounds\ of\ total\ O_2\ demand\ per\ hour =$$
$$33.4\ lbs\ BOD_5/hr \times 1.2\ O_2 lbs/lbBOD_5 + 2.09\ lbsNH_3/hr \times 4.6\ O_2/lbsNH_3$$
$$= 49.7\ lbs\ O_2/hr$$

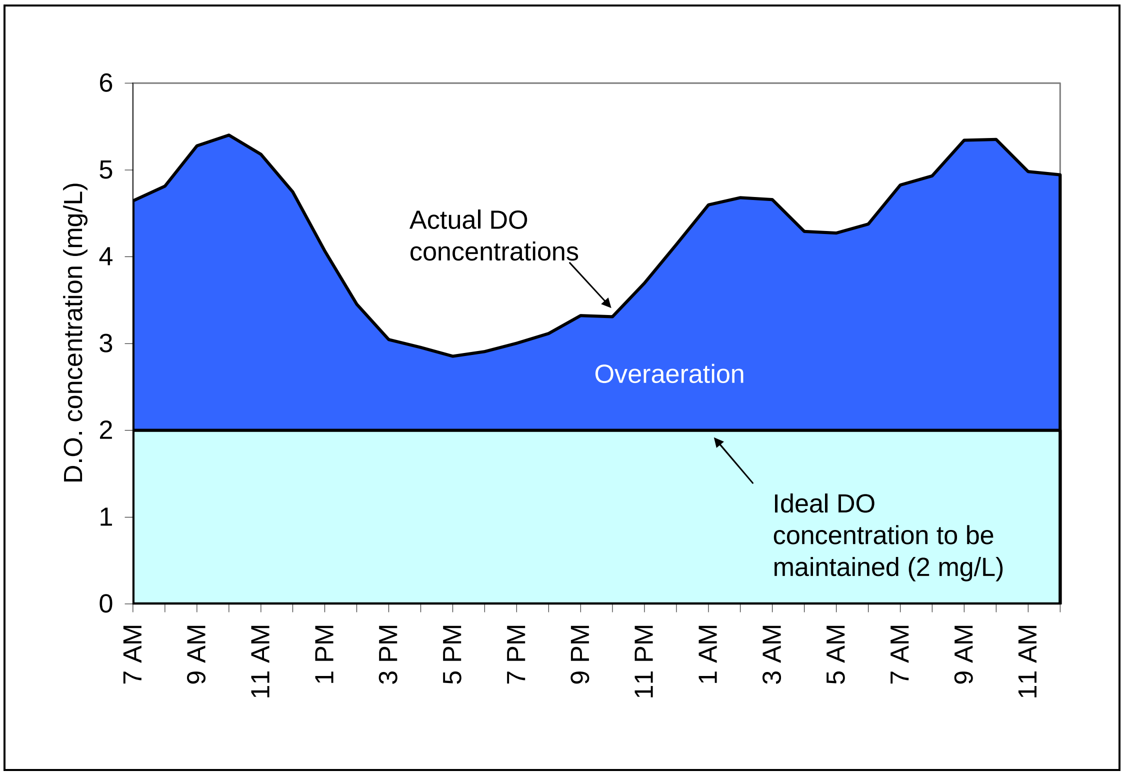
Data from the manufacturer can be used to calculate the amount of oxygen supplied at the selected aeration settings. For example, when the disc immersion at 15" at 55 RPM, in Apex Forward direction, the total supplied oxygen is calculated as follows:

$$264\ Discs \times 1.39\ O_2 lbs/hr \times 0.8(site\_factor) = 294\ lbs/hr$$

Thus, when the aeration system is operated in this mode during the high flow period, the total amount of oxygen supplied is 294 lbs O_2/hr, which is close to the calculated oxygen demand of 237 lbs O_2/hr. However, the oxygen required for the low flow time period is 49.7 lbs O_2/hr, which is about one fifth the amount supplied by the aeration discs at their high flow settings. Plant staff explored manually switching some drives to low speed during the night, but found it was difficult to consistently match oxygen supply with demand since flow and wastewater strength are constantly changing. Moreover, if too little oxygen is supplied, untreated wastewater could pass through the system and possibly result in permit violations. Thus, plant operators typically erred on the side of providing too much oxygen, and the ditch was often found to be in an over-aerated state. This practice wastes energy and makes for unstable biological conditions. Research literature discusses the disadvantage of over-aerated mixed liquor, which forms pin flocs at the sedimentation basin. Pin flocs remain in suspension and reduce the effluent quality after secondary treatment.

U.S. Filter/Envirex Inc. suggests the ditch channel oxygen to be operated in a "0-1-2" mode, which maintains the oxygen level at approximately 0 mg/L for the outer channel, 1 mg/L for the middle channel and 2 mg/L for the innermost channel. This mode of the operation is designed to ensure the ditch achieves proper BOD, ammonia, and nitrate removal. At a constant aeration rate, dissolved oxygen in the outer channel was found to be relatively stable, typically varying from 0.4 mg/L to 0.8 mg/L with an average of 0.5 mg/L. In contrast, the innermost channel experienced a wide swing in DO throughout the day. Figure 4 illustrates typical weekday DO levels in the innermost channel during manual aeration. The oxygen level in the innermost channel increased from 3.0 mg/L at 9 PM to 5.4 mg/L at 10 AM next day. The daily fluctuations in DO levels were even larger during the weekend when campus wastewater flows were lower.

Figure 4. DO Levels in the Innermost Oxidation Ditch Channel under Manual Aeration



3.1 Process Control Modifications

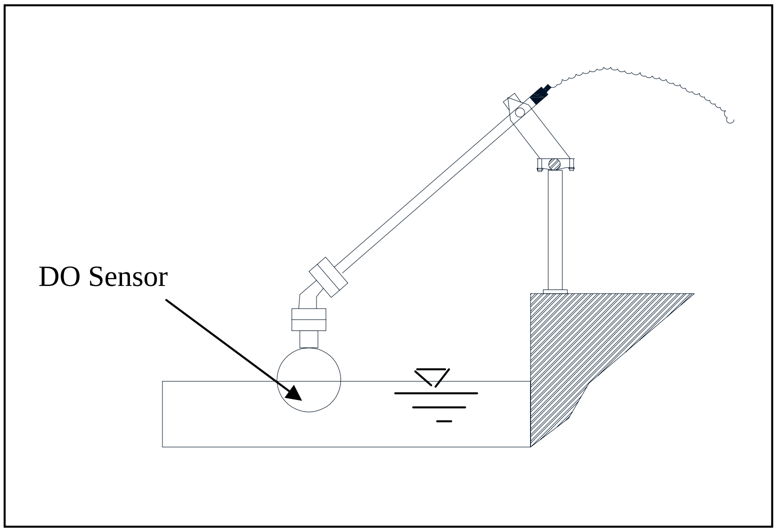
Several physical and process control changes were identified to keep aeration in line with biological demand. First, the amount of oxygen supplied by the aerators in the Orbal system could be better controlled if variable-frequency drives (VFDs) were installed on some of the motors. A VFD is an electronic controller that adjusts the speed of an electric motor by modulating the power being delivered. For the UC Davis system, only two VFDs were considered necessary to affect this change, as the existing constant-speed motors for the remaining aerators are needed to provide the baseline aeration required for low-flow periods. Equally important, speed control for the VFDs could be provided through a feedback control loop in response to actual DO levels in the innermost channel. After making these changes, the two VFD aerators would then only operate as required to maintain set-point oxygen levels in the innermost channel. The speed of the VFDs would increase in proportion to the demand in response to actual DO levels. Logic control would be performed using existing Programmable Logic Controller (PLC) and Supervisory Control and Data Acquisition (SCADA) system.

The amount of energy saved can be estimated by comparing the minimum aeration settings under the original design to the theoretical power needed to provide the required oxygen. The average total oxygen demand in the winter, allowing for partial denitrification, at the design flow rate of 2.5 Mgd is 3,757 lbs O_2 per day. The aerators can achieve an efficiency of about 0.9 kgO_2/kWh, which means the average daily power requirement for aeration is about 106 hp (Metcalf and Eddy, 1991). Before making the design changes, the lowest power consumption was 180 hp (two outer aerators on high at 25 hp each, two inner aerators on high at 40 hp each, and two inner aerators on low at 25 hp each). Thus, the nominal power savings provided by these design changes is estimated to average 74 hp, or 530 kWh/Mg at 2.5 Mgd. Greater savings would be expected when plant flows are lower (e.g., 1,030 kWh/Mg at 1.8 Mgd).

3.2 On-line Continuous DO Monitoring

The idea of using an on-line DO meter to control aeration systems is not new and has been suggested in many designs. However, few installations have been operated successfully due to the limitations inherent with previous on-line DO monitoring devices. Traditional on-line DO monitoring devices are not well suited for continuous use in the activated sludge process. Operation and maintenance problems were especially severe for biological processes like oxidation ditches with a long Mean Cell Retention Time (MCRT) where the primary clarifiers are eliminated. Without primary clarifiers, debris like plastic and rags are often found in the ditch channels, and they quickly tangle around traditional DO sensors, causing inaccurate readings. Plant operators often find excessive maintenance and calibration are required to keep the DO meters in service. In response to these problems, a new debris-free type of DO monitoring device, as shown in Figure 5, was selected for the DO loop control at UC Davis. The device consists of a float ball, where the DO sensor is mounted near the bottom of the ball. Half of the float ball is immersed under water. Because of its smooth surface, no debris can grab on the sensor, and so debris does not affect the accuracy of the DO readings.

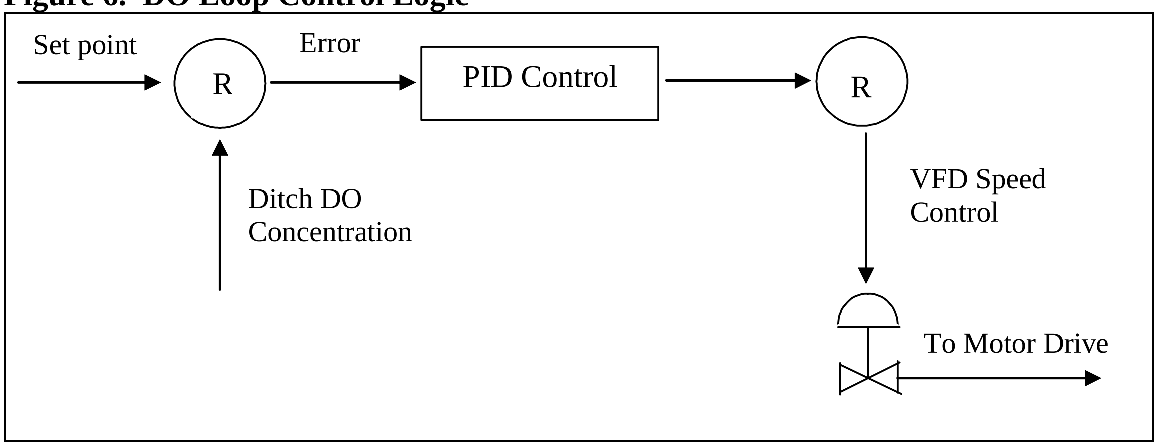
Figure 5. Cerlic® Float Ball DO Monitor



3.3 Control Strategy

The DO loop control holds the dissolved oxygen level inside the ditch at a desired set point. Figure 6 shows the logic loop control.

Figure 6. DO Loop Control Logic



Under DO control, the PID controls the process by sending an output to the VFDs, and the VFDs then regulate the motor speeds accordingly. The greater the error between a pre-set DO value and the DO from the ditch on-line DO meter, the faster the disc drive runs, and vice versa. This control strategy allows the amount of oxygen delivered by the aeration system to match the oxygen demand and thus eliminate over-aeration, with a resultant power reduction.

4.1 Implementation

The Cerlic® float-ball DO monitoring device was mounted on the ditch inner wall along with the enclosed probe analyzer box, which is powered by an uninterrupted power supply (UPS). The UPS was powered by an existing 120-volt AC outlet. The DO analyzer was connected to the SCADA in the plant administration building via an existing conduit. To verify proper operation, plant staff record DO levels in the channel each day using a portable DO meter and compare these results to the on-line data.

Two Danfoss VLT®8000 Variable Frequency Drives (VFD) were installed to replace the existing 2-speed motors. The other two aerators on the innermost channel were set to run continuously at a constant low speed to satisfy the minimum oxygen demand during low loading time periods. The SCADA system was modified to communicate with the two VFDs to throttle the speed of the aerators to maintain a DO setpoint of 2.0 mg/L. Delays were programmed into the control logic to provide smooth transitions and avoid excessive cycling.

Under DO control, the PLC controls the process by sending an output to the VFDs, and the VFDs then regulate the motor speeds accordingly. The greater the error between a pre-set DO value and the DO from the ditch on-line DO meter, the faster the disc drive runs, and vice versa. This control strategy allows the amount of oxygen delivered by the aeration system to match the oxygen demand and thus eliminate over-aeration, with a resultant power reduction.

These modifications were started in late November 2003 and were completed at the end of December 2004. The total cost for design, construction, and startup was approximately $64,000. This estimate includes all labor provided by the UC Davis WWTP staff, even though these costs reflect a redirection of internal resources rather than additional expenses.

4.2 Energy Use

Shortly after start-up, we installed power monitors on the two modified aerator motors to compare the original design with the revised design. In the first phase of this test, the two VFDs were set to run in a 2-speed mode just as they were manually operated before the VFDs were installed. In the second phase of the test, the VFDs were set to run automatically under DO loop control during similar flow conditions. In each case, power draw was recorded using data loggers at five minutes intervals. As shown in Figure 7, power consumption after installing the VFDs varies closely in response to the flow pattern while only minor changes were possible via 2-speed motor control.

There was a clear reduction in power consumption following implementation of the process control changes. Total power consumption for the WWTP was reduced by an average of 6%. This reduction in energy use occurred while flows to the WWTP increased by an average of nearly 20%. Figure 8 shows total WWTP energy use per million gallon of effluent treated to account for the increase in flow over the study period.

During the first year of operation, the use of VFDs for oxidation ditch aeration in conjunction with DO feedback-loop control reduced total WWTP electrical consumption by an average of 23% or 755 kilowatt-hours per million gallons (kWh/Mg).

Figure 7. Typical Electrical Use Before and After Process Control Changes

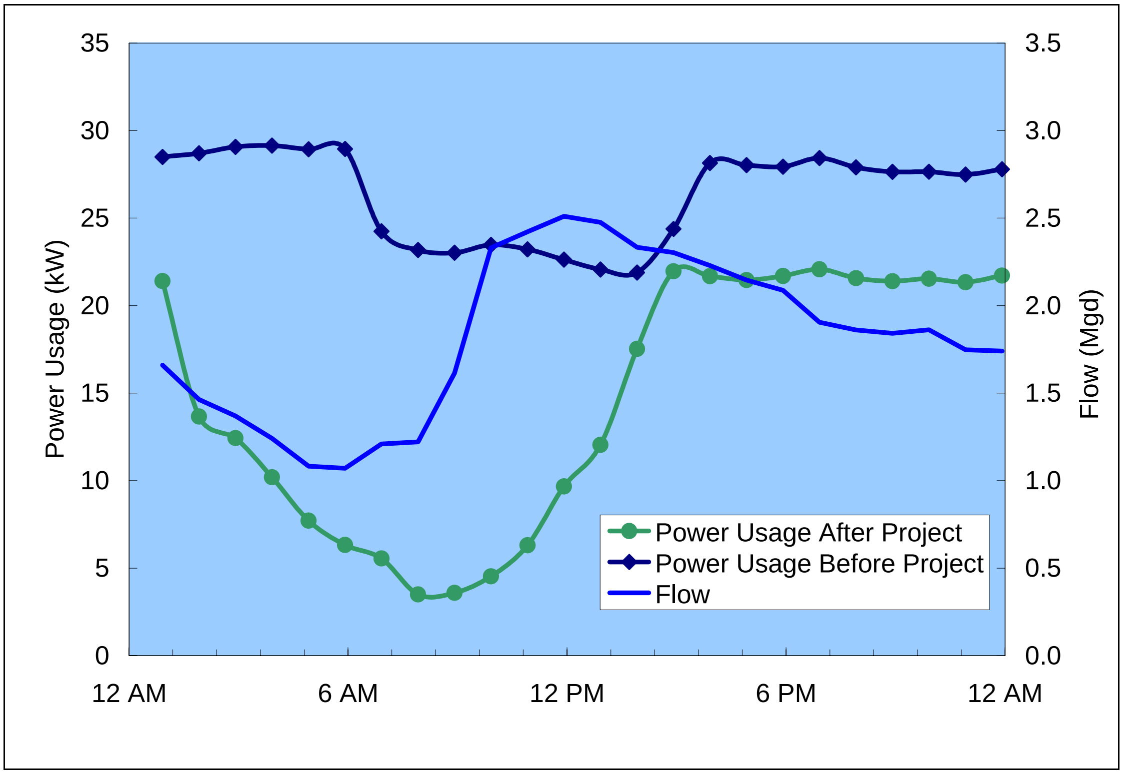
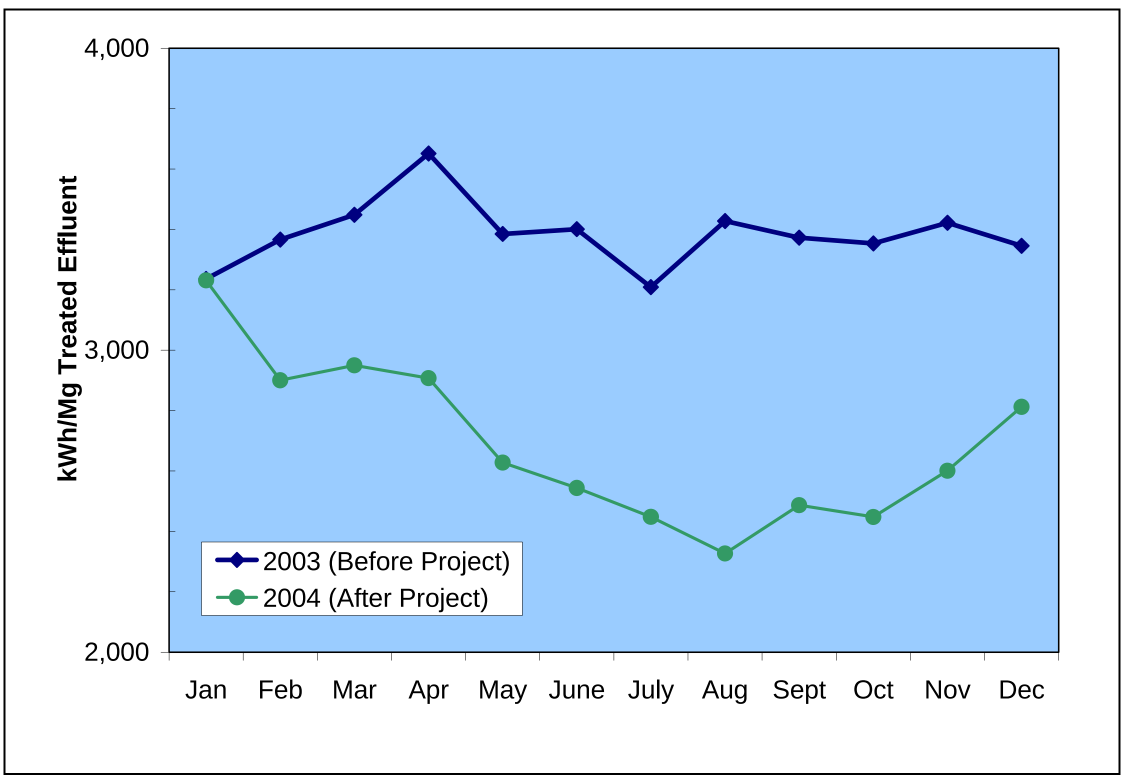
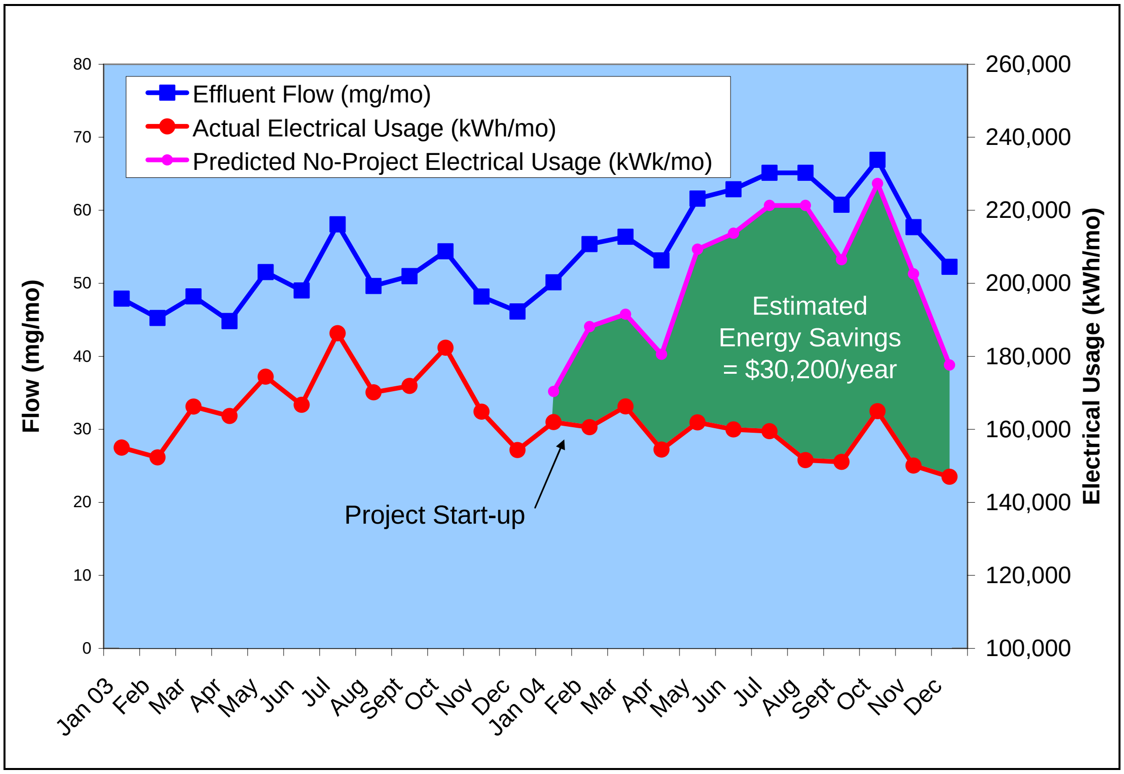


Figure 8—Flow-adjusted WWTP Electrical Use



UC Davis buys electricity for the relatively low rate of $0.054/kWh, but the project nonetheless resulted in a noticeable decrease in WWTP operating costs. While the campus was experiencing a period of significant growth, energy use by the WWTP actually decreased. Had the project not been implemented, energy use was projected to have increased significantly. Figure 9 shows projected and actual energy use for the WWTP. We estimate that the project saved the University approximately $30,200 during the first year of operation. This savings represents approximately 3% of the total annual operation and maintenance budget for the WWTP.

Figure 9. Estimated Project Energy Savings



4.3 Water Quality

Tables 5 and 6 summarize key water quality parameters before and after the design changes were made. The WWTP continued to produce high-quality effluent, meeting all permit conditions in the months following implementation of the project. The SVI (Sludge Volume Index) showed some slight change. The SVI is an indicator of sludge quality and should be maintained in the range of 100 to 180. Before the process control changes were made, the WWTP typically operated below this range. The SVI went from an average of 84 in 2003 to 99 in 2004. This change reflects a modest improvement in treatment. Additional monitoring is necessary to evaluate more subtle water quality affects, like how the change in particle size distribution might be influenced by the creation of stable oxygen concentrations in the secondary treatment process.

Table 5. Secondary Treatment Water Quality (Prior to Filtration)

Month	2003				2004			
	TSS	Turbidity	SVI	pH	TSS	Turbidity	SVI	pH
January	8.6	2.24	60	7.62	8.0	2.55	93	7.87
February	7.0	1.95	71	7.62	11.9	3.52	112	7.55
March	7.0	2.2	68	7.68	5.2	1.56	99	7.65
April	4.8	1.71	83	7.60	4.7	1.45	162	7.62
May	5.2	1.73	85	7.99	5.3	0.33	115	7.95
June	5.8	1.97	82	7.92	8.9	2.88	106	8.04
July	5.3	1.93	76	7.96	7.3	2.24	67	8.08
August	6.5	2.04	83	7.92	11.0	2.97	67	8.00
September	8.4	2.41	75	7.97	8.6	2.64	98	8.02
October	10.4	1.87	112	7.95	8.2	1.89	89	8.05
November	7.4	2.38	111	7.98	6.0	1.69	85	7.97
December	8.19	2.53	104	8.06	6.5	2.05	89	7.96
Average	**7.05**	**2.08**	**84**	**7.86**	**7.64**	**2.15**	**99**	**7.90**

Table 6. Effluent Water Quality after Tertiary Treatment

Month	2003				2004			
	TSS	Turbidity	BOD_5	NH_3-N	TSS	Turbidity	BOD_5	NH_3-N
January	0.92	1.58	1.72	<0.5	0.64	0.33	1.27	<0.5
February	0.51	0.59	1.18	<0.5	2.20	1.97	1.66	<0.5
March	1.00	0.91	1.65	<0.5	0.40	0.45	1.31	<0.5
April	1.20	1.38	1.44	0.87	0.19	0.46	0.57	<0.5
May	0.92	0.93	1.25	<0.5	0.25	0.33	1.34	<0.5
June	1.04	0.52	1.17	<0.5	0.91	0.91	2.00	<0.5
July	0.54	0.40	1.35	<0.5	0.47	0.45	1.28	<0.5
August	0.66	0.47	1.57	<0.5	0.37	0.45	1.19	<0.5
September	0.65	0.64	1.85	<0.5	0.27	0.53	0.95	<0.5
October	0.40	0.35	1.80	<0.5	0.30	0.52	1.63	<0.5
November	0.32	0.37	1.19	<0.5	0.40	0.74	2.50	<0.5
December	0.59	0.48	1.10	<0.5	1.00	0.74	1.96	<0.5
Average	**0.73**	**1.12**	**1.44**	**0.87**	**0.62**	**0.80**	**1.47**	**<0.5**

The data collected thus far suggest that final effluent water quality has, on average, slightly improved after installing the VFDs. Ammonia as nitrogen remained below 0.5 mg/L in 2004 while removal varied in 2003. This was expected since the DO loop control provides instantaneous adjustment to match the in-coming oxygen demand. Under manual control, aeration could only be set based on an average load. Thus, if there were a sudden increase in the influent ammonia concentrations, some ammonia would bleed through the oxidation ditch. Beyond these metrics, the WWTP operators strongly prefer the new process control system, as it provides an extremely stable biological treatment process.

The process control changes necessary to automate oxidation ditch aeration at the UC Davis WWTP were relatively easy to implement and our data indicates that the project has significantly reduced energy use while maintaining or improving effluent water quality. After twelve months of operation, our principal conclusions are as follows:

- The availability of a debris-free, low-maintenance, in-line DO meter is an important innovation that makes automatic DO loop control operationally practical for activated sludge treatment systems. The tested DO monitoring system has proven to be extremely reliable with very little maintenance required. The automated control system has consistently maintained set-point DO levels in the oxidation ditch without discernable drift or error.

- The use of VFDs for oxidation ditch aeration in conjunction with DO feedback-loop control has reduced WWTP electrical consumption by an average of 23% or 755 kilowatt-hours per million gallons (kWh/Mg) (Figure 9). The project was found to have a 1.2 year payback at the prevailing municipal electrical rate of $0.09/kWh.

- Beyond energy efficiency, the ability to maintain DO at prescribed levels in the oxidation ditch has afforded operators a higher degree of biological process control. Effluent quality has improved as a result. The sludge volume index (SVI) increased from an average of 84 to 99. Ammonia as nitrogen has consistently remained below 0.5 mg/L after implementation.

- The revised system was designed to consistently maintain DO at fixed levels with the goal of maintaining a stable biological treatment process. However, other control strategies that vary DO levels over time are also possible. Use of variable DO control strategies might allow for a further reduction in energy consumption or enhanced biological treatment. These concepts are recommended for future study.

Given these positive results, operators of existing activated sludge WWTPs with manual aeration and designers of new WWTPs should consider implementing similar process control strategies.

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APPENDIX A, Electric Usage Records

Electric Usage Records

After the Project				Before the Poject			
Record Date	Record End Time	Aerator 2012 Avg. kW	Aerator 2014 Avg. kW	Record Date	Record End Time	Aerator 2013 Avg. kW	Aerator 2011 Avg. kW
4/5/2004	10:50:00	5.912	9.937	4/12/2004	10:55:00	23.664	45.764
4/5/2004	10:55:00	6.132	9.962	4/12/2004	11:00:00	23.586	45.759
4/5/2004	11:00:00	6.286	10.082	4/12/2004	11:05:00	23.591	45.933
4/5/2004	11:05:00	5.835	10.325	4/12/2004	11:10:00	23.67	45.672
4/5/2004	11:10:00	5.229	9.941	4/12/2004	11:15:00	23.644	45.807
4/5/2004	11:15:00	5.39	9.361	4/12/2004	11:20:00	23.641	46.126
4/5/2004	11:20:00	7.005	9.486	4/12/2004	11:25:00	23.631	45.851
4/5/2004	11:25:00	10.165	11.131	4/12/2004	11:30:00	23.638	45.642
4/5/2004	11:30:00	9.084	13.016	4/12/2004	11:35:00	23.561	46.053
4/5/2004	11:35:00	6.007	13.218	4/12/2004	11:40:00	23.561	45.765
4/5/2004	11:40:00	6.062	10.17	4/12/2004	11:45:00	23.617	45.542
4/5/2004	11:45:00	9.903	10.309	4/12/2004	11:50:00	23.643	45.985
4/5/2004	11:50:00	15.869	11.762	4/12/2004	11:55:00	23.551	46.059
4/5/2004	11:55:00	13.403	18.047	4/12/2004	12:00:00	23.825	45.574
4/5/2004	12:00:00	8.19	16.076	4/12/2004	12:05:00	23.792	45.786
4/5/2004	12:05:00	6.794	11.873	4/12/2004	12:10:00	23.883	46.089
4/5/2004	12:10:00	10.675	10.978	4/12/2004	12:15:00	23.802	46.096
4/5/2004	12:15:00	16.599	14.225	4/12/2004	12:20:00	23.784	45.754
4/5/2004	12:20:00	14.504	18.782	4/12/2004	12:25:00	23.706	45.956
4/5/2004	12:25:00	8.074	17.157	4/12/2004	12:30:00	23.614	45.708
4/5/2004	12:30:00	6.837	11.776	4/12/2004	12:35:00	23.517	45.274
4/5/2004	12:35:00	13.432	11.152	4/12/2004	12:40:00	23.39	44.935
4/5/2004	12:40:00	18.027	16.58	4/12/2004	12:45:00	23.243	44.327
4/5/2004	12:45:00	11.315	19.888	4/12/2004	12:50:00	23.271	43.777
4/5/2004	12:50:00	10.289	14.8	4/12/2004	12:55:00	23.284	43.774
4/5/2004	12:55:00	17.741	13.359	4/12/2004	13:00:00	23.297	43.967
4/5/2004	13:00:00	18.75	19.628	4/12/2004	13:05:00	23.164	43.802
4/5/2004	13:05:00	12.535	20.384	4/12/2004	13:10:00	23.231	43.407
4/5/2004	13:10:00	10.629	15.624	4/12/2004	13:15:00	23.384	43.696
4/5/2004	13:15:00	16.008	14.209	4/12/2004	13:20:00	23.312	44.036
4/5/2004	13:20:00	22.43	18.585	4/12/2004	13:25:00	23.272	43.902
4/5/2004	13:25:00	21.541	23.153	4/12/2004	13:30:00	23.501	43.805
4/5/2004	13:30:00	16.527	22.387	4/12/2004	13:35:00	23.522	44.094
4/5/2004	13:35:00	16.859	18.735	4/12/2004	13:40:00	23.464	44.032
4/5/2004	13:40:00	24.496	19.067	4/12/2004	13:45:00	23.374	43.942
4/5/2004	13:45:00	27.88	24.625	4/12/2004	13:50:00	23.355	43.92
4/5/2004	13:50:00	20.339	26.863	4/12/2004	13:55:00	23.321	43.935
4/5/2004	13:55:00	22.77	21.578	4/12/2004	14:00:00	23.158	43.727
4/5/2004	14:00:00	27.97	23.399	4/12/2004	14:05:00	23.107	43.409
4/5/2004	14:05:00	21.771	26.958	4/12/2004	14:10:00	23.183	43.185
4/5/2004	14:10:00	20.516	22.592	4/12/2004	14:15:00	23.157	43.406
4/5/2004	14:15:00	27.868	21.78	4/12/2004	14:20:00	22.998	43.225
4/5/2004	14:20:00	28.835	26.832	4/12/2004	14:25:00	22.991	42.953
4/5/2004	14:25:00	21.996	27.484	4/12/2004	14:30:00	23.114	42.798
4/5/2004	14:30:00	19.678	22.641	4/12/2004	14:35:00	23.18	43.078
4/5/2004	14:35:00	30.755	21.218	4/12/2004	14:40:00	23.128	43.09
4/5/2004	14:40:00	30.277	30.082	4/12/2004	14:45:00	23.097	43.031

Electric Usage Records

After the Project				Before the Poject			
Record Date	Record End Time	Aerator 2012 Avg. kW	Aerator 2014 Avg. kW	Record Date	Record End Time	Aerator 2013 Avg. kW	Aerator 2011 Avg. kW
4/5/2004	14:45:00	23.284	31.127	4/12/2004	14:50:00	23.104	42.967
4/5/2004	14:50:00	24.095	26.808	4/12/2004	14:55:00	29.972	42.991
4/5/2004	14:55:00	30.159	27.407	4/12/2004	15:00:00	41.319	42.877
4/5/2004	15:00:00	27.533	30.877	4/12/2004	15:05:00	41.528	42.861
4/5/2004	15:05:00	26.156	30.287	4/12/2004	15:10:00	41.786	43.027
4/5/2004	15:10:00	28.63	29.368	4/12/2004	15:15:00	41.659	43.334
4/5/2004	15:15:00	31.163	30.987	4/12/2004	15:20:00	41.329	43.197
4/5/2004	15:20:00	30.595	33.609	4/12/2004	15:25:00	41.115	42.929
4/5/2004	15:25:00	25.973	30.509	4/12/2004	15:30:00	41.301	42.772
4/5/2004	15:30:00	32.082	29.087	4/12/2004	15:35:00	41.191	42.993
4/5/2004	15:35:00	29.157	33.326	4/12/2004	15:40:00	41.107	42.881
4/5/2004	15:40:00	30.87	31.745	4/12/2004	15:45:00	41.059	42.768
4/5/2004	15:45:00	31.841	33.888	4/12/2004	15:50:00	41.212	42.771
4/5/2004	15:50:00	32.704	32.745	4/12/2004	15:55:00	41.229	42.907
4/5/2004	15:55:00	32.447	33.994	4/12/2004	16:00:00	41.198	42.907
4/5/2004	16:00:00	32.129	33.837	4/12/2004	16:05:00	41.185	42.878
4/5/2004	16:05:00	32.314	34.39	4/12/2004	16:10:00	41.059	42.907
4/5/2004	16:10:00	32.279	33.044	4/12/2004	16:15:00	41.068	42.844
4/5/2004	16:15:00	31.973	33.485	4/12/2004	16:20:00	41.006	42.823
4/5/2004	16:20:00	31.716	33.193	4/12/2004	16:25:00	40.838	42.797
4/5/2004	16:25:00	31.698	32.966	4/12/2004	16:30:00	40.78	42.639
4/5/2004	16:30:00	31.678	32.95	4/12/2004	16:35:00	41.107	42.662
4/5/2004	16:35:00	31.732	33.049	4/12/2004	16:40:00	41.198	42.928
4/5/2004	16:40:00	31.834	33.216	4/12/2004	16:45:00	41.378	43.068
4/5/2004	16:45:00	31.736	33.228	4/12/2004	16:50:00	41.368	43.209
4/5/2004	16:50:00	30.753	33.188	4/12/2004	16:55:00	41.449	43.252
4/5/2004	16:55:00	31.806	33.144	4/12/2004	17:00:00	41.305	43.269
4/5/2004	17:00:00	31.714	32.972	4/12/2004	17:05:00	41.176	43.184
4/5/2004	17:05:00	31.609	32.889	4/12/2004	17:10:00	41.051	43.034
4/5/2004	17:10:00	31.583	32.669	4/12/2004	17:15:00	41.117	42.969
4/5/2004	17:15:00	31.566	32.634	4/12/2004	17:20:00	41.197	43.059
4/5/2004	17:20:00	31.73	32.688	4/12/2004	17:25:00	41.114	43.054
4/5/2004	17:25:00	31.618	32.993	4/12/2004	17:30:00	41.036	43.009
4/5/2004	17:30:00	30.866	34.061	4/12/2004	17:35:00	41.19	43.006
4/5/2004	17:35:00	31.719	32.831	4/12/2004	17:40:00	41.212	43.169
4/5/2004	17:40:00	31.853	32.891	4/12/2004	17:45:00	41.219	43.153
4/5/2004	17:45:00	31.75	32.902	4/12/2004	17:50:00	41.72	43.198
4/5/2004	17:50:00	31.756	32.793	4/12/2004	17:55:00	42.178	43.657
4/5/2004	17:55:00	31.747	32.651	4/12/2004	18:00:00	42.313	44.107
4/5/2004	18:00:00	31.47	32.753	4/12/2004	18:05:00	42.093	44.164
4/5/2004	18:05:00	31.713	33.681	4/12/2004	18:10:00	41.505	43.946
4/5/2004	18:10:00	31.699	32.859	4/12/2004	18:15:00	41.667	43.51
4/5/2004	18:15:00	31.62	32.77	4/12/2004	18:20:00	41.636	43.583
4/5/2004	18:20:00	31.598	32.48	4/12/2004	18:25:00	41.327	43.534
4/5/2004	18:25:00	31.577	32.683	4/12/2004	18:30:00	41.19	43.271
4/5/2004	18:30:00	31.745	32.525	4/12/2004	18:35:00	41.194	43.13
4/5/2004	18:35:00	31.738	32.655	4/12/2004	18:40:00	41.097	43.115
4/5/2004	18:40:00	31.655	32.793	4/12/2004	18:45:00	40.83	43.066

Electric Usage Records

After the Project				Before the Poject			
Record Date	Record End Time	Aerator 2012 Avg. kW	Aerator 2014 Avg. kW	Record Date	Record End Time	Aerator 2013 Avg. kW	Aerator 2011 Avg. kW
4/5/2004	18:45:00	31.493	32.887	4/12/2004	18:50:00	40.975	42.869
4/5/2004	18:50:00	31.763	32.936	4/12/2004	18:55:00	41.116	42.937
4/5/2004	18:55:00	31.587	33.201	4/12/2004	19:00:00	41.058	43.101
4/5/2004	19:00:00	32.222	33.407	4/12/2004	19:05:00	40.949	43.037
4/5/2004	19:05:00	32.29	33.603	4/12/2004	19:10:00	40.952	42.946
4/5/2004	19:10:00	32.268	33.68	4/12/2004	19:15:00	40.792	42.911
4/5/2004	19:15:00	32.231	33.467	4/12/2004	19:20:00	40.747	42.784
4/5/2004	19:20:00	32.292	33.482	4/12/2004	19:25:00	40.921	42.73
4/5/2004	19:25:00	32.294	33.476	4/12/2004	19:30:00	40.922	42.875
4/5/2004	19:30:00	32.348	32.78	4/12/2004	19:35:00	40.782	42.892
4/5/2004	19:35:00	32.499	33.701	4/12/2004	19:40:00	40.834	42.802
4/5/2004	19:40:00	32.41	33.71	4/12/2004	19:45:00	40.868	42.787
4/5/2004	19:45:00	32.383	33.543	4/12/2004	19:50:00	40.755	42.776
4/5/2004	19:50:00	32.242	25.986	4/12/2004	19:55:00	40.652	42.685
4/5/2004	19:55:00	32.122	33.531	4/12/2004	20:00:00	40.488	42.557
4/5/2004	20:00:00	31.756	33.447	4/12/2004	20:05:00	40.507	42.465
4/5/2004	20:05:00	31.546	33.233	4/12/2004	20:10:00	40.537	42.49
4/5/2004	20:10:00	31.532	33.074	4/12/2004	20:15:00	40.624	42.47
4/5/2004	20:15:00	31.606	32.815	4/12/2004	20:20:00	40.52	42.555
4/5/2004	20:20:00	31.56	32.553	4/12/2004	20:25:00	40.425	42.434
4/5/2004	20:25:00	31.332	32.349	4/12/2004	20:30:00	40.534	42.414
4/5/2004	20:30:00	31.315	32.468	4/12/2004	20:35:00	40.467	42.45
4/5/2004	20:35:00	31.275	32.822	4/12/2004	20:40:00	40.52	42.326
4/5/2004	20:40:00	31.123	32.9	4/12/2004	20:45:00	40.486	42.365
4/5/2004	20:45:00	31.438	31.719	4/12/2004	20:50:00	40.643	42.422
4/5/2004	20:50:00	31.248	33.093	4/12/2004	20:55:00	40.705	42.601
4/5/2004	20:55:00	31.409	32.805	4/12/2004	21:00:00	40.931	42.633
4/5/2004	21:00:00	31.538	32.308	4/12/2004	21:05:00	41.137	42.905
4/5/2004	21:05:00	31.472	32.349	4/12/2004	21:10:00	41.156	42.992
4/5/2004	21:10:00	31.55	32.619	4/12/2004	21:15:00	41.253	43.005
4/5/2004	21:15:00	31.496	33.041	4/12/2004	21:20:00	41.463	43.153
4/5/2004	21:20:00	31.325	33.061	4/12/2004	21:25:00	41.45	43.286
4/5/2004	21:25:00	31.21	32.446	4/12/2004	21:30:00	41.333	43.274
4/5/2004	21:30:00	31.295	31.947	4/12/2004	21:35:00	41.447	43.275
4/5/2004	21:35:00	31.305	32.32	4/12/2004	21:40:00	41.505	43.339
4/5/2004	21:40:00	31.343	32.894	4/12/2004	21:45:00	41.523	43.372
4/5/2004	21:45:00	31.372	32.921	4/12/2004	21:50:00	41.325	43.456
4/5/2004	21:50:00	31.273	32.558	4/12/2004	21:55:00	41.226	43.274
4/5/2004	21:55:00	31.258	32.096	4/12/2004	22:00:00	41.275	43.165
4/5/2004	22:00:00	31.118	32.336	4/12/2004	22:05:00	41.379	43.165
4/5/2004	22:05:00	31.2	32.785	4/12/2004	22:10:00	41.062	43.262
4/5/2004	22:10:00	31.241	32.621	4/12/2004	22:15:00	40.519	42.973
4/5/2004	22:15:00	31.442	32.205	4/12/2004	22:20:00	40.419	42.493
4/5/2004	22:20:00	31.212	32.217	4/12/2004	22:25:00	40.417	42.364
4/5/2004	22:25:00	31.217	32.704	4/12/2004	22:30:00	40.483	42.34
4/5/2004	22:30:00	31.22	32.933	4/12/2004	22:35:00	40.602	42.527
4/5/2004	22:35:00	31.351	32.411	4/12/2004	22:40:00	40.535	42.672
4/5/2004	22:40:00	31.528	32.1	4/12/2004	22:45:00	40.37	42.451

Electric Usage Records

After the Project				Before the Poject			
Record Date	Record End Time	Aerator 2012 Avg. kW	Aerator 2014 Avg. kW	Record Date	Record End Time	Aerator 2013 Avg. kW	Aerator 2011 Avg. kW
4/5/2004	22:45:00	31.819	32.61	4/12/2004	22:50:00	40.455	42.308
4/5/2004	22:50:00	31.882	33.395	4/12/2004	22:55:00	40.458	42.415
4/5/2004	22:55:00	31.872	33.515	4/12/2004	23:00:00	40.414	42.396
4/5/2004	23:00:00	31.781	33.15	4/12/2004	23:05:00	40.349	42.48
4/5/2004	23:05:00	31.665	32.714	4/12/2004	23:10:00	40.31	42.354
4/5/2004	23:10:00	31.648	32.59	4/12/2004	23:15:00	40.283	42.224
4/5/2004	23:15:00	31.65	33.091	4/12/2004	23:20:00	40.421	42.21
4/5/2004	23:20:00	31.377	33.268	4/12/2004	23:25:00	40.658	42.451
4/5/2004	23:25:00	31.212	32.733	4/12/2004	23:30:00	40.79	42.71
4/5/2004	23:30:00	31.125	31.94	4/12/2004	23:35:00	40.63	42.702
4/5/2004	23:35:00	31.049	32.232	4/12/2004	23:40:00	40.736	42.55
4/5/2004	23:40:00	31.088	32.811	4/12/2004	23:45:00	40.9	42.75
4/5/2004	23:45:00	31.237	32.399	4/12/2004	23:50:00	40.903	42.887
4/5/2004	23:50:00	31.171	31.959	4/12/2004	23:55:00	41.12	42.82
4/5/2004	23:55:00	31.313	32.369	4/13/2004	0:00:00	41.357	42.977
4/6/2004	0:00:00	31.377	32.981	4/13/2004	0:05:00	41.892	43.268
4/6/2004	0:05:00	31.53	32.703	4/13/2004	0:10:00	42.006	43.329
4/6/2004	0:10:00	31.531	32.088	4/13/2004	0:15:00	42.053	43.413
4/6/2004	0:15:00	31.567	32.371	4/13/2004	0:20:00	41.653	43.477
4/6/2004	0:20:00	31.499	32.977	4/13/2004	0:25:00	41.856	42.948
4/6/2004	0:25:00	31.597	32.679	4/13/2004	0:30:00	41.946	43.205
4/6/2004	0:30:00	31.646	32.156	4/13/2004	0:35:00	41.938	43.3
4/6/2004	0:35:00	31.713	32.446	4/13/2004	0:40:00	41.873	43.356
4/6/2004	0:40:00	31.674	33.122	4/13/2004	0:45:00	41.889	43.297
4/6/2004	0:45:00	31.626	32.785	4/13/2004	0:50:00	42.146	43.373
4/6/2004	0:50:00	31.445	32.146	4/13/2004	0:55:00	42.08	43.561
4/6/2004	0:55:00	31.853	32.187	4/13/2004	1:00:00	41.9	43.394
4/6/2004	1:00:00	31.88	32.349	4/13/2004	1:05:00	41.955	43.229
4/6/2004	1:05:00	30.093	32.324	4/13/2004	1:10:00	41.809	43.341
4/6/2004	1:10:00	29.906	31.818	4/13/2004	1:15:00	41.823	43.181
4/6/2004	1:15:00	27.621	30.809	4/13/2004	1:20:00	42.128	43.331
4/6/2004	1:20:00	28.889	29.983	4/13/2004	1:25:00	42.175	43.576
4/6/2004	1:25:00	28.298	30.931	4/13/2004	1:30:00	42.128	43.641
4/6/2004	1:30:00	23.205	30.208	4/13/2004	1:35:00	42.174	43.614
4/6/2004	1:35:00	22.933	26.722	4/13/2004	1:40:00	42.136	43.688
4/6/2004	1:40:00	22.926	26.546	4/13/2004	1:45:00	42.191	43.658
4/6/2004	1:45:00	22.83	26.445	4/13/2004	1:50:00	42.302	43.751
4/6/2004	1:50:00	21.034	26.462	4/13/2004	1:55:00	42.267	43.905
4/6/2004	1:55:00	18.009	25.149	4/13/2004	2:00:00	42.101	43.832
4/6/2004	2:00:00	21.315	22.982	4/13/2004	2:05:00	42.053	43.614
4/6/2004	2:05:00	18.816	25.599	4/13/2004	2:10:00	42.16	43.538
4/6/2004	2:10:00	16.012	23.537	4/13/2004	2:15:00	42.349	43.867
4/6/2004	2:15:00	21.212	21.399	4/13/2004	2:20:00	42.482	44.076
4/6/2004	2:20:00	21.086	25.56	4/13/2004	2:25:00	42.604	44.278
4/6/2004	2:25:00	14.802	25.227	4/13/2004	2:30:00	42.422	44.381
4/6/2004	2:30:00	16.201	20.449	4/13/2004	2:35:00	42.346	44.231
4/6/2004	2:35:00	18.42	21.546	4/13/2004	2:40:00	42.54	44.195
4/6/2004	2:40:00	18.084	23.217	4/13/2004	2:45:00	42.598	44.288

Electric Usage Records

After the Project				Before the Poject			
Record Date	Record End Time	Aerator 2012 Avg. kW	Aerator 2014 Avg. kW	Record Date	Record End Time	Aerator 2013 Avg. kW	Aerator 2011 Avg. kW
4/6/2004	2:45:00	14.488	22.997	4/13/2004	2:50:00	42.739	44.427
4/6/2004	2:50:00	13.346	19.979	4/13/2004	2:55:00	42.714	44.561
4/6/2004	2:55:00	15.862	19.23	4/13/2004	3:00:00	42.727	44.498
4/6/2004	3:00:00	15.032	21.437	4/13/2004	3:05:00	42.737	44.449
4/6/2004	3:05:00	13.353	20.775	4/13/2004	3:10:00	42.552	44.492
4/6/2004	3:10:00	14.114	19.371	4/13/2004	3:15:00	42.555	44.337
4/6/2004	3:15:00	14.329	20.015	4/13/2004	3:20:00	42.835	44.401
4/6/2004	3:20:00	12.534	20.144	4/13/2004	3:25:00	42.869	44.588
4/6/2004	3:25:00	12.902	18.839	4/13/2004	3:30:00	42.872	44.587
4/6/2004	3:30:00	12.984	19.165	4/13/2004	3:35:00	42.718	44.632
4/6/2004	3:35:00	11.752	19.092	4/13/2004	3:40:00	42.604	44.48
4/6/2004	3:40:00	11.982	18.126	4/13/2004	3:45:00	42.677	44.369
4/6/2004	3:45:00	11.242	18.469	4/13/2004	3:50:00	42.802	44.45
4/6/2004	3:50:00	10.082	17.723	4/13/2004	3:55:00	42.835	44.584
4/6/2004	3:55:00	12.132	16.767	4/13/2004	4:00:00	42.672	44.595
4/6/2004	4:00:00	11.805	18.466	4/13/2004	4:05:00	42.571	44.426
4/6/2004	4:05:00	9.7	18.17	4/13/2004	4:10:00	42.467	44.308
4/6/2004	4:10:00	8.696	16.433	4/13/2004	4:15:00	42.386	44.229
4/6/2004	4:15:00	9.507	15.605	4/13/2004	4:20:00	42.454	44.185
4/6/2004	4:20:00	12.154	16.337	4/13/2004	4:25:00	42.653	44.193
4/6/2004	4:25:00	12.715	18.432	4/13/2004	4:30:00	42.552	44.414
4/6/2004	4:30:00	8.134	18.926	4/13/2004	4:35:00	42.473	44.359
4/6/2004	4:35:00	6.949	14.912	4/13/2004	4:40:00	42.378	44.236
4/6/2004	4:40:00	8.422	14.108	4/13/2004	4:45:00	42.413	44.153
4/6/2004	4:45:00	9.443	15.16	4/13/2004	4:50:00	42.425	44.169
4/6/2004	4:50:00	9.165	16.085	4/13/2004	4:55:00	42.472	44.112
4/6/2004	4:55:00	8.217	15.925	4/13/2004	5:00:00	42.575	44.321
4/6/2004	5:00:00	5.948	14.937	4/13/2004	5:05:00	42.531	44.325
4/6/2004	5:05:00	6.69	13.03	4/13/2004	5:10:00	42.474	44.312
4/6/2004	5:10:00	8.952	13.352	4/13/2004	5:15:00	42.539	44.208
4/6/2004	5:15:00	7.621	15.819	4/13/2004	5:20:00	42.416	44.246
4/6/2004	5:20:00	5.654	14.488	4/13/2004	5:25:00	42.607	44.174
4/6/2004	5:25:00	6.073	12.28	4/13/2004	5:30:00	42.496	44.33
4/6/2004	5:30:00	6.583	13.19	4/13/2004	5:35:00	42.466	44.22
4/6/2004	5:35:00	6.409	13.356	4/13/2004	5:40:00	42.549	44.183
4/6/2004	5:40:00	5.383	13.57	4/13/2004	5:45:00	42.394	44.215
4/6/2004	5:45:00	4.747	12.085	4/13/2004	5:50:00	42.583	44.102
4/6/2004	5:50:00	5.092	11.297	4/13/2004	5:55:00	42.585	44.298
4/6/2004	5:55:00	6.229	11.682	4/13/2004	6:00:00	42.468	44.274
4/6/2004	6:00:00	5.946	12.752	4/13/2004	6:05:00	42.275	44.21
4/6/2004	6:05:00	4.707	11.906	4/13/2004	6:10:00	42.289	44.025
4/6/2004	6:10:00	4.179	11.111	4/13/2004	6:15:00	42.212	44.1
4/6/2004	6:15:00	4.244	10.346	4/13/2004	6:20:00	42.311	43.986
4/6/2004	6:20:00	4.858	10.639	4/13/2004	6:25:00	42.54	44.073
4/6/2004	6:25:00	4.981	11.257	4/13/2004	6:30:00	42.561	44.29
4/6/2004	6:30:00	4.914	11.477	4/13/2004	6:35:00	42.668	44.261
4/6/2004	6:35:00	4.493	11.4	4/13/2004	6:40:00	42.803	44.387
4/6/2004	6:40:00	3.884	10.972	4/13/2004	6:45:00	42.718	44.47

Electric Usage Records

After the Project				Before the Poject			
Record Date	Record End Time	Aerator 2012 Avg. kW	Aerator 2014 Avg. kW	Record Date	Record End Time	Aerator 2013 Avg. kW	Aerator 2011 Avg. kW
4/6/2004	6:45:00	2.994	10.055	4/13/2004	6:50:00	42.722	44.433
4/6/2004	6:50:00	3.953	8.74	4/13/2004	6:55:00	28.114	44.423
4/6/2004	6:55:00	5.1	10.109	4/13/2004	7:00:00	23.72	44.607
4/6/2004	7:00:00	4.499	11.561	4/13/2004	7:05:00	23.697	44.611
4/6/2004	7:05:00	3.399	10.726	4/13/2004	7:10:00	23.73	44.613
4/6/2004	7:10:00	2.85	9.358	4/13/2004	7:15:00	23.706	44.512
4/6/2004	7:15:00	2.749	8.539	4/13/2004	7:20:00	23.743	44.69
4/6/2004	7:20:00	3.103	8.392	4/13/2004	7:25:00	23.771	44.788
4/6/2004	7:25:00	3.694	8.877	4/13/2004	7:30:00	23.786	44.829
4/6/2004	7:30:00	3.638	9.668	4/13/2004	7:35:00	23.745	44.771
4/6/2004	7:35:00	2.974	9.554	4/13/2004	7:40:00	23.798	44.678
4/6/2004	7:40:00	2.58	8.688	4/13/2004	7:45:00	23.86	44.798
4/6/2004	7:45:00	2.673	8.192	4/13/2004	7:50:00	11.865	44.998
4/6/2004	7:50:00	2.727	8.224	4/13/2004	7:55:00	24.136	23.888
4/6/2004	7:55:00	2.503	8.318	4/13/2004	8:00:00	24.214	45.378
4/6/2004	8:00:00	2.207	8.003	4/13/2004	8:05:00	24.271	45.303
4/6/2004	8:05:00	2.541	7.522	4/13/2004	8:10:00	24.256	45.587
4/6/2004	8:10:00	2.694	8.108	4/13/2004	8:15:00	24.253	45.551
4/6/2004	8:15:00	2.943	8.349	4/13/2004	8:20:00	24.285	45.719
4/6/2004	8:20:00	2.663	8.741	4/13/2004	8:25:00	24.198	45.913
4/6/2004	8:25:00	2.2	8.37	4/13/2004	8:30:00	24.165	45.693
4/6/2004	8:30:00	1.91	7.567	4/13/2004	8:35:00	24.081	45.407
4/6/2004	8:35:00	1.999	7.202	4/13/2004	8:40:00	24.055	45.168
4/6/2004	8:40:00	2.514	7.294	4/13/2004	8:45:00	24.063	44.948
4/6/2004	8:45:00	2.483	8.115	4/13/2004	8:50:00	24.028	44.825
4/6/2004	8:50:00	2.704	8.08	4/13/2004	8:55:00	24.095	44.826
4/6/2004	8:55:00	2.556	8.468	4/13/2004	9:00:00	24.077	44.973
4/6/2004	9:00:00	2.495	8.209	4/13/2004	9:05:00	24.176	45.116
4/6/2004	9:05:00	2.272	8.132	4/13/2004	9:10:00	24.178	45.317
4/6/2004	9:10:00	2.536	7.892	4/13/2004	9:15:00	24.126	45.305
4/6/2004	9:15:00	3.181	8.297	4/13/2004	9:20:00	24.11	45.263
4/6/2004	9:20:00	3.501	9.224	4/13/2004	9:25:00	24.124	45
4/6/2004	9:25:00	3.158	9.618	4/13/2004	9:30:00	24.161	44.956
4/6/2004	9:30:00	3.401	9.148	4/13/2004	9:35:00	24.188	45.169
4/6/2004	9:35:00	3.628	9.525	4/13/2004	9:40:00	24.141	45.257
4/6/2004	9:40:00	3.579	9.747	4/13/2004	9:45:00	24.147	45.372
4/6/2004	9:45:00	4.359	9.783	4/13/2004	9:50:00	24.319	45.297
4/6/2004	9:50:00	4.219	10.781	4/13/2004	9:55:00	24.416	45.779
4/6/2004	9:55:00	3.708	10.45	4/13/2004	10:00:00	24.372	45.996
4/6/2004	10:00:00	4.071	9.908	4/13/2004	10:05:00	24.287	45.956
4/6/2004	10:05:00	4.994	10.44	4/13/2004	10:10:00	24.299	46.086
4/6/2004	10:10:00	5.223	11.619	4/13/2004	10:15:00	24.316	46.142
4/6/2004	10:15:00	5.489	11.855	4/13/2004	10:20:00	24.235	45.915
4/6/2004	10:20:00	5.881	12.152	4/13/2004	10:25:00	24.223	45.793
4/6/2004	10:25:00	5.179	12.645	4/13/2004	10:30:00	24.187	45.852
4/6/2004	10:30:00	5.477	11.923	4/13/2004	10:35:00	24.243	45.842
4/6/2004	10:35:00	7.263	12.37	4/13/2004	10:40:00	24.201	45.671
4/6/2004	10:40:00	8.045	14.251	4/13/2004	10:45:00	24.106	45.626

Electric Usage Records

After the Project				Before the Poject			
Record Date	Record End Time	Aerator 2012 Avg. kW	Aerator 2014 Avg. kW	Record Date	Record End Time	Aerator 2013 Avg. kW	Aerator 2011 Avg. kW
4/6/2004	10:45:00	8.179	14.967	4/13/2004	10:50:00	23.994	45.55
4/6/2004	10:50:00	6.647	14.951	4/13/2004	10:55:00	24.056	45.455
4/6/2004	10:55:00	5.933	13.353	4/13/2004	11:00:00	24.171	45.572
4/6/2004	11:00:00	8.428	12.999	4/13/2004	11:05:00	24.266	45.878
4/6/2004	11:05:00	9.627	15.42	4/13/2004	11:10:00	24.283	46.405
4/6/2004	11:10:00	8.31	16.199	4/13/2004	11:15:00	24.26	46.362
4/6/2004	11:15:00	6.527	15.08	4/13/2004	11:20:00	24.255	46.249
4/6/2004	11:20:00	7.071	12.788	4/13/2004	11:25:00	24.217	46.179
4/6/2004	11:25:00	7.797	14.016	4/13/2004	11:30:00	23.823	45.837
4/6/2004	11:30:00	9.03	14.585	4/13/2004	11:35:00	23.511	43.994
4/6/2004	11:35:00	8.885	15.556	4/13/2004	11:40:00	23.74	43.364
4/6/2004	11:40:00	9.699	15.523	4/13/2004	11:45:00	23.918	44.129
4/6/2004	11:45:00	10.892	16.308	4/13/2004	11:50:00	23.891	44.736
4/6/2004	11:50:00	11.248	14.876	4/13/2004	11:55:00	23.813	44.578
4/6/2004	11:55:00	11.331	17.588	4/13/2004	12:00:00	23.758	44.067
4/6/2004	12:00:00	12.071	17.691	4/13/2004	12:05:00	23.623	44.134
4/6/2004	12:05:00	12.178	18.3	4/13/2004	12:10:00	23.593	44.123
4/6/2004	12:10:00	10.125	18.276	4/13/2004	12:15:00	23.616	44.033
4/6/2004	12:15:00	10.698	16.453	4/13/2004	12:20:00	23.488	43.943
4/6/2004	12:20:00	14.348	17.128	4/13/2004	12:25:00	23.373	43.578
4/6/2004	12:25:00	13.708	20.096	4/13/2004	12:30:00	23.345	43.318
4/6/2004	12:30:00	11.558	19.584	4/13/2004	12:35:00	23.324	43.183
4/6/2004	12:35:00	12.251	17.728	4/13/2004	12:40:00	23.37	43.124
4/6/2004	12:40:00	15.099	18.445	4/13/2004	12:45:00	23.376	43.387
4/6/2004	12:45:00	17.557	20.913	4/13/2004	12:50:00	23.245	43.44
4/6/2004	12:50:00	15.034	22.731	4/13/2004	12:55:00	23.207	43.195
4/6/2004	12:55:00	15.218	20.687	4/13/2004	13:00:00	23.294	42.985
4/6/2004	13:00:00	18.291	20.927	4/13/2004	13:05:00	23.361	43.122
4/6/2004	13:05:00	20.587	23.468	4/13/2004	13:10:00	23.257	43.221
4/6/2004	13:10:00	17.631	25.162	4/13/2004	13:15:00	23.234	42.988
4/6/2004	13:15:00	14.269	22.684	4/13/2004	13:20:00	23.168	42.912
4/6/2004	13:20:00	21.233	20.093	4/13/2004	13:25:00	23.185	42.835
4/6/2004	13:25:00	19.463	25.611	4/13/2004	13:30:00	23.282	42.894
4/6/2004	13:30:00	18.054	24.22	4/13/2004	13:35:00	23.21	43.047
4/6/2004	13:35:00	19.343	23.124	4/13/2004	13:40:00	23.157	42.941
4/6/2004	13:40:00	23.421	24.199	4/13/2004	13:45:00	23.188	42.772
4/6/2004	13:45:00	21.133	27.339	4/13/2004	13:50:00	23.117	42.825
4/6/2004	13:50:00	20.19	25.608	4/13/2004	13:55:00	23.074	42.714
4/6/2004	13:55:00	24.338	24.996	4/13/2004	14:00:00	23.013	42.578
4/6/2004	14:00:00	28.763	28.241	4/13/2004	14:05:00	23.068	42.469
4/6/2004	14:05:00	27.771	31.513	4/13/2004	14:10:00	23.052	42.622
4/6/2004	14:10:00	24.043	30.528	4/13/2004	14:15:00	23.146	42.613
4/6/2004	14:15:00	27.822	27.888	4/13/2004	14:20:00	23.256	42.834
4/6/2004	14:20:00	30.617	30.524	4/13/2004	14:25:00	23.24	43.061
4/6/2004	14:25:00	29.147	32.439	4/13/2004	14:30:00	23.274	43.265
4/6/2004	14:30:00	31.177	31.691	4/13/2004	14:35:00	23.374	43.374
4/6/2004	14:35:00	27.781	33.202	4/13/2004	14:40:00	23.299	43.512
4/6/2004	14:40:00	26.774	29.931	4/13/2004	14:45:00	23.287	43.383

Electric Usage Records

After the Project				Before the Poject			
Record Date	Record End Time	Aerator 2012 Avg. kW	Aerator 2014 Avg. kW	Record Date	Record End Time	Aerator 2013 Avg. kW	Aerator 2011 Avg. kW
4/6/2004	14:45:00	29.471	29.366	4/13/2004	14:50:00	23.261	43.391
4/6/2004	14:50:00	28.53	31.414	4/13/2004	14:55:00	30.243	43.305
4/6/2004	14:55:00	32.282	30.68	4/13/2004	15:00:00	41.327	42.893
4/6/2004	15:00:00	32.358	33.615	4/13/2004	15:05:00	41.316	42.778
4/6/2004	15:05:00	31.794	34.309	4/13/2004	15:10:00	41.361	42.931
4/6/2004	15:10:00	31.795	32.023	4/13/2004	15:15:00	41.288	42.967
4/6/2004	15:15:00	31.915	32.048	4/13/2004	15:20:00	41.228	42.891
4/6/2004	15:20:00	31.914	32.717	4/13/2004	15:25:00	41.137	42.895
4/6/2004	15:25:00	31.99	32.714	4/13/2004	15:30:00	41.286	42.842
4/6/2004	15:30:00	31.881	32.963	4/13/2004	15:35:00	41.293	42.974
4/6/2004	15:35:00	31.865	32.943	4/13/2004	15:40:00	41.123	42.951
4/6/2004	15:40:00	31.987	33.011	4/13/2004	15:45:00	41.223	42.828
4/6/2004	15:45:00	32.02	33.074	4/13/2004	15:50:00	41.535	43.127
4/6/2004	15:50:00	31.98	33.093	4/13/2004	15:55:00	41.328	43.464
4/6/2004	15:55:00	31.654	32.23	4/13/2004	16:00:00	41.225	43.109
4/6/2004	16:00:00	31.826	33.393	4/13/2004	16:05:00	41.174	43.02
4/6/2004	16:05:00	31.989	34.106	4/13/2004	16:10:00	41.262	42.942
4/6/2004	16:10:00	31.902	32.686	4/13/2004	16:15:00	41.364	43.116
4/6/2004	16:15:00	31.861	32.674	4/13/2004	16:20:00	41.239	43.169
4/6/2004	16:20:00	31.909	32.622	4/13/2004	16:25:00	41.14	42.995
4/6/2004	16:25:00	32.004	32.777	4/13/2004	16:30:00	41.134	42.94
4/6/2004	16:30:00	31.948	32.956	4/13/2004	16:35:00	41.205	42.916
4/6/2004	16:35:00	31.848	32.954	4/13/2004	16:40:00	41.201	43.03
4/6/2004	16:40:00	31.878	32.937	4/13/2004	16:45:00	41.072	42.948
4/6/2004	16:45:00	31.913	32.951	4/13/2004	16:50:00	41.072	42.923
4/6/2004	16:50:00	31.783	32.963	4/13/2004	16:55:00	41.137	42.888
4/6/2004	16:55:00	31.77	32.799	4/13/2004	17:00:00	41.273	42.938
4/6/2004	17:00:00	31.836	32.614	4/13/2004	17:05:00	41.212	43.151
4/6/2004	17:05:00	32.032	32.723	4/13/2004	17:10:00	41.143	43.056
4/6/2004	17:10:00	31.888	32.803	4/13/2004	17:15:00	41.191	43.022
4/6/2004	17:15:00	31.8	32.678	4/13/2004	17:20:00	41.358	43.12
4/6/2004	17:20:00	31.908	32.625	4/13/2004	17:25:00	41.4	43.241
4/6/2004	17:25:00	31.899	32.573	4/13/2004	17:30:00	41	43.262
4/6/2004	17:30:00	31.821	32.739	4/13/2004	17:35:00	40.94	42.911
4/6/2004	17:35:00	31.737	32.676	4/13/2004	17:40:00	40.983	42.79
4/6/2004	17:40:00	31.761	32.645	4/13/2004	17:45:00	41.041	42.91
4/6/2004	17:45:00	31.935	32.768	4/13/2004	17:50:00	40.96	42.971
4/6/2004	17:50:00	31.922	32.896	4/13/2004	17:55:00	40.958	42.871
4/6/2004	17:55:00	32.054	32.931	4/13/2004	18:00:00	40.91	42.851
4/6/2004	18:00:00	32.302	33.028	4/13/2004	18:05:00	41.159	42.837
4/6/2004	18:05:00	32.508	33.261	4/13/2004	18:10:00	41.439	43.111
4/6/2004	18:10:00	32.536	33.46	4/13/2004	18:15:00	41.552	43.415
4/6/2004	18:15:00	32.557	33.464	4/13/2004	18:20:00	41.549	43.471
4/6/2004	18:20:00	32.43	33.462	4/13/2004	18:25:00	41.668	43.464
4/6/2004	18:25:00	32.757	33.431	4/13/2004	18:30:00	41.798	43.624
4/6/2004	18:30:00	32.795	33.661	4/13/2004	18:35:00	41.739	43.683
4/6/2004	18:35:00	32.643	33.661	4/13/2004	18:40:00	41.692	43.605
4/6/2004	18:40:00	32.678	33.523	4/13/2004	18:45:00	41.779	43.567

Electric Usage Records

After the Project				Before the Poject			
Record Date	Record End Time	Aerator 2012 Avg. kW	Aerator 2014 Avg. kW	Record Date	Record End Time	Aerator 2013 Avg. kW	Aerator 2011 Avg. kW
4/6/2004	18:45:00	32.696	33.56	4/13/2004	18:50:00	41.881	43.712
4/6/2004	18:50:00	32.855	33.526	4/13/2004	18:55:00	41.691	43.768
4/6/2004	18:55:00	32.652	33.705	4/13/2004	19:00:00	41.622	43.607
4/6/2004	19:00:00	32.603	33.576	4/13/2004	19:05:00	41.632	43.552
4/6/2004	19:05:00	32.664	33.619	4/13/2004	19:10:00	41.748	43.572
4/6/2004	19:10:00	32.748	33.589	4/13/2004	19:15:00	41.731	43.662
4/6/2004	19:15:00	32.521	33.697	4/13/2004	19:20:00	41.576	43.59
4/6/2004	19:20:00	32.136	33.58	4/13/2004	19:25:00	41.569	43.5
4/6/2004	19:25:00	32.03	33.181	4/13/2004	19:30:00	41.768	43.463
4/6/2004	19:30:00	32.003	32.994	4/13/2004	19:35:00	41.832	43.689
4/6/2004	19:35:00	32.029	32.925	4/13/2004	19:40:00	41.647	43.782
4/6/2004	19:40:00	31.967	32.8	4/13/2004	19:45:00	41.436	43.569
4/6/2004	19:45:00	31.931	32.697	4/13/2004	19:50:00	41.21	43.208
4/6/2004	19:50:00	31.75	26.851	4/13/2004	19:55:00	40.924	43.067
4/6/2004	19:55:00	31.766	32.977	4/13/2004	20:00:00	40.672	42.773
4/6/2004	20:00:00	31.704	32.95	4/13/2004	20:05:00	40.518	42.498
4/6/2004	20:05:00	31.708	32.803	4/13/2004	20:10:00	40.454	42.362
4/6/2004	20:10:00	31.559	32.521	4/13/2004	20:15:00	40.479	42.334
4/6/2004	20:15:00	31.689	32.374	4/13/2004	20:20:00	40.454	42.368
4/6/2004	20:20:00	31.79	32.374	4/13/2004	20:25:00	40.441	42.344
4/6/2004	20:25:00	31.694	32.531	4/13/2004	20:30:00	40.432	42.269
4/6/2004	20:30:00	31.683	32.574	4/13/2004	20:35:00	40.525	42.252
4/6/2004	20:35:00	31.682	32.768	4/13/2004	20:40:00	40.586	42.366
4/6/2004	20:40:00	31.807	32.876	4/13/2004	20:45:00	40.603	42.412
4/6/2004	20:45:00	31.833	32.986	4/13/2004	20:50:00	40.598	42.592
4/6/2004	20:50:00	31.743	32.91	4/13/2004	20:55:00	40.5	42.575
4/6/2004	20:55:00	31.757	32.557	4/13/2004	21:00:00	40.603	42.423
4/6/2004	21:00:00	31.836	32.436	4/13/2004	21:05:00	40.628	42.493
4/6/2004	21:05:00	31.844	32.383	4/13/2004	21:10:00	40.644	42.498
4/6/2004	21:10:00	31.847	32.617	4/13/2004	21:15:00	40.594	42.55
4/6/2004	21:15:00	31.719	32.887	4/13/2004	21:20:00	40.601	42.47
4/6/2004	21:20:00	31.502	32.903	4/13/2004	21:25:00	40.618	42.414
4/6/2004	21:25:00	31.569	32.845	4/13/2004	21:30:00	40.555	42.465
4/6/2004	21:30:00	31.677	32.725	4/13/2004	21:35:00	40.587	42.442
4/6/2004	21:35:00	31.654	32.493	4/13/2004	21:40:00	40.518	42.558
4/6/2004	21:40:00	31.682	32.325	4/13/2004	21:45:00	40.516	42.482
4/6/2004	21:45:00	31.615	32.329	4/13/2004	21:50:00	40.637	42.372
4/6/2004	21:50:00	31.76	32.523	4/13/2004	21:55:00	40.564	42.489
4/6/2004	21:55:00	31.678	32.959	4/13/2004	22:00:00	40.451	42.372
4/6/2004	22:00:00	31.479	32.941	4/13/2004	22:05:00	40.382	42.273
4/6/2004	22:05:00	31.521	32.523	4/13/2004	22:10:00	40.568	42.301
4/6/2004	22:10:00	31.537	32.21	4/13/2004	22:15:00	40.73	42.502
4/6/2004	22:15:00	31.711	32.07	4/13/2004	22:20:00	40.498	42.648
4/6/2004	22:20:00	31.599	32.525	4/13/2004	22:25:00	40.367	42.322
4/6/2004	22:25:00	31.615	32.797	4/13/2004	22:30:00	40.306	42.265
4/6/2004	22:30:00	31.541	32.925	4/13/2004	22:35:00	40.428	42.059
4/6/2004	22:35:00	31.456	32.503	4/13/2004	22:40:00	40.383	42.225
4/6/2004	22:40:00	31.544	31.995	4/13/2004	22:45:00	40.285	42.208

Electric Usage Records

After the Project				Before the Poject			
Record Date	Record End Time	Aerator 2012 Avg. kW	Aerator 2014 Avg. kW	Record Date	Record End Time	Aerator 2013 Avg. kW	Aerator 2011 Avg. kW
4/6/2004	22:45:00	31.579	32.257	4/13/2004	22:50:00	40.251	42.149
4/6/2004	22:50:00	31.473	32.753	4/13/2004	22:55:00	40.266	42.161
4/6/2004	22:55:00	31.52	32.871	4/13/2004	23:00:00	40.476	42.191
4/6/2004	23:00:00	31.546	32.494	4/13/2004	23:05:00	40.537	42.367
4/6/2004	23:05:00	31.575	32.047	4/13/2004	23:10:00	40.495	42.352
4/6/2004	23:10:00	31.5	32.247	4/13/2004	23:15:00	40.558	42.311
4/6/2004	23:15:00	31.421	32.72	4/13/2004	23:20:00	40.612	42.386
4/6/2004	23:20:00	31.369	32.803	4/13/2004	23:25:00	40.686	42.506
4/6/2004	23:25:00	31.527	32.273	4/13/2004	23:30:00	40.647	42.598
4/6/2004	23:30:00	31.885	32.057	4/13/2004	23:35:00	40.607	42.547
4/6/2004	23:35:00	32.155	32.651	4/13/2004	23:40:00	40.634	42.517
4/6/2004	23:40:00	32.245	33.263	4/13/2004	23:45:00	40.667	42.516
4/6/2004	23:45:00	32.276	33.601	4/13/2004	23:50:00	40.8	42.505
4/6/2004	23:50:00	32.335	33.416	4/13/2004	23:55:00	40.747	42.685
4/6/2004	23:55:00	32.241	33.172	4/14/2004	0:00:00	40.773	42.636
4/7/2004	0:00:00	32.402	32.91	4/14/2004	0:05:00	40.752	42.722
4/7/2004	0:05:00	31.991	33.076	4/14/2004	0:10:00	40.799	42.766
4/7/2004	0:10:00	31.647	33.201	4/14/2004	0:15:00	40.961	42.751
4/7/2004	0:15:00	31.402	33.207	4/14/2004	0:20:00	40.931	43.011
4/7/2004	0:20:00	31.457	33.07	4/14/2004	0:25:00	40.832	42.975
4/7/2004	0:25:00	31.482	32.717	4/14/2004	0:30:00	40.819	42.889
4/7/2004	0:30:00	31.623	32.471	4/14/2004	0:35:00	40.882	42.781
4/7/2004	0:35:00	31.497	32.517	4/14/2004	0:40:00	41.11	42.951
4/7/2004	0:40:00	31.435	32.702	4/14/2004	0:45:00	41.018	43.126
4/7/2004	0:45:00	31.362	32.918	4/14/2004	0:50:00	41.012	43.025
4/7/2004	0:50:00	31.386	33.012	4/14/2004	0:55:00	41.189	43.053
4/7/2004	0:55:00	31.479	32.82	4/14/2004	1:00:00	41.13	43.291
4/7/2004	1:00:00	31.488	32.584	4/14/2004	1:05:00	41.205	43.195
4/7/2004	1:05:00	31.51	32.381	4/14/2004	1:10:00	41.204	43.322
4/7/2004	1:10:00	31.476	32.454	4/14/2004	1:15:00	41.104	43.267
4/7/2004	1:15:00	31.566	32.838	4/14/2004	1:20:00	40.988	43.201
4/7/2004	1:20:00	31.578	33.021	4/14/2004	1:25:00	41.072	42.995
4/7/2004	1:25:00	31.616	32.951	4/14/2004	1:30:00	41.2	43.095
4/7/2004	1:30:00	31.595	32.669	4/14/2004	1:35:00	41.197	43.261
4/7/2004	1:35:00	31.359	32.406	4/14/2004	1:40:00	41.17	43.308
4/7/2004	1:40:00	31.314	32.336	4/14/2004	1:45:00	41.041	43.375
4/7/2004	1:45:00	31.305	32.705	4/14/2004	1:50:00	41.178	43.223
4/7/2004	1:50:00	31.439	32.951	4/14/2004	1:55:00	41.361	43.364
4/7/2004	1:55:00	31.444	32.883	4/14/2004	2:00:00	41.279	43.551
4/7/2004	2:00:00	31.373	32.452	4/14/2004	2:05:00	41.225	43.461
4/7/2004	2:05:00	31.328	32.17	4/14/2004	2:10:00	41.159	43.368
4/7/2004	2:10:00	31.226	32.436	4/14/2004	2:15:00	41.115	43.279
4/7/2004	2:15:00	30.241	32.878	4/14/2004	2:20:00	41.325	43.258
4/7/2004	2:20:00	24.948	31.812	4/14/2004	2:25:00	41.458	43.61
4/7/2004	2:25:00	19.627	27.914	4/14/2004	2:30:00	41.462	43.756
4/7/2004	2:30:00	22.331	23.964	4/14/2004	2:35:00	41.349	43.777
4/7/2004	2:35:00	21.315	25.966	4/14/2004	2:40:00	41.391	43.587
4/7/2004	2:40:00	19.498	25.016	4/14/2004	2:45:00	41.402	43.593

Electric Usage Records

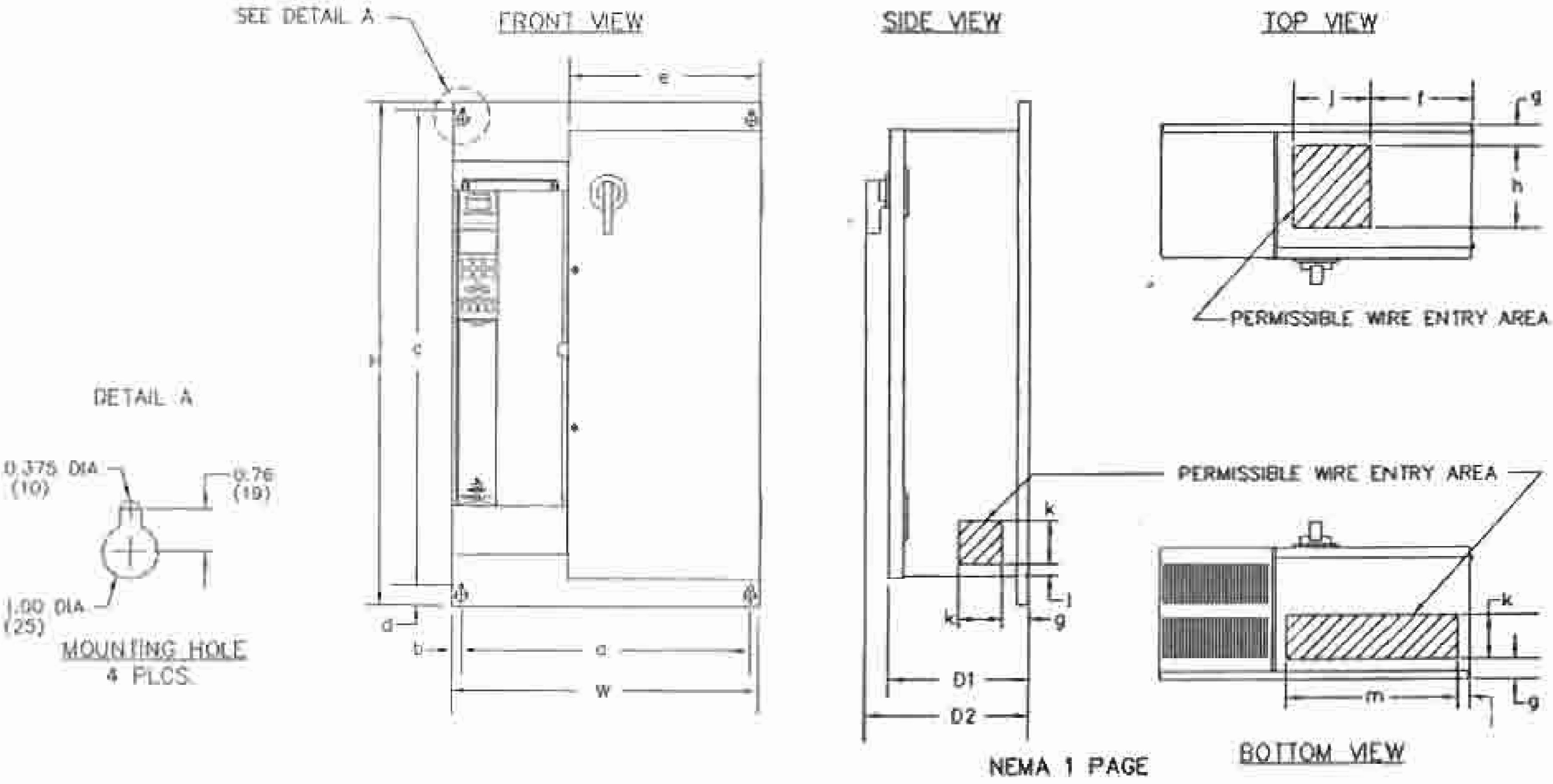
After the Project				Before the Poject			
Record Date	Record End Time	Aerator 2012 Avg. kW	Aerator 2014 Avg. kW	Record Date	Record End Time	Aerator 2013 Avg. kW	Aerator 2011 Avg. kW
4/7/2004	2:45:00	17.065	23.687	4/14/2004	2:50:00	41.486	43.578
4/7/2004	2:50:00	18.391	21.754	4/14/2004	2:55:00	41.415	43.671
4/7/2004	2:55:00	18.805	22.91	4/14/2004	3:00:00	41.304	43.622
4/7/2004	3:00:00	18.653	23.267	4/14/2004	3:05:00	41.288	43.626
4/7/2004	3:05:00	13.693	23.115	4/14/2004	3:10:00	41.436	43.612
4/7/2004	3:10:00	16.82	19.102	4/14/2004	3:15:00	41.823	43.896
4/7/2004	3:15:00	20.052	21.814	4/14/2004	3:20:00	41.911	44.208
4/7/2004	3:20:00	16.408	24.13	4/14/2004	3:25:00	41.889	44.354
4/7/2004	3:25:00	13.182	21.357	4/14/2004	3:30:00	41.839	44.324
4/7/2004	3:30:00	16.118	18.868	4/14/2004	3:35:00	41.726	44.277
4/7/2004	3:35:00	19.543	21.279	4/14/2004	3:40:00	41.831	44.11
4/7/2004	3:40:00	14.843	23.883	4/14/2004	3:45:00	42.053	44.225
4/7/2004	3:45:00	12.679	20.059	4/14/2004	3:50:00	42.053	44.383
4/7/2004	3:50:00	14.714	18.343	4/14/2004	3:55:00	42.04	44.387
4/7/2004	3:55:00	15.116	20.136	4/14/2004	4:00:00	42.079	44.326
4/7/2004	4:00:00	12.44	20.293	4/14/2004	4:05:00	42.275	44.318
4/7/2004	4:05:00	14.011	18.144	4/14/2004	4:10:00	42.396	44.484
4/7/2004	4:10:00	12.847	19.543	4/14/2004	4:15:00	42.35	44.518
4/7/2004	4:15:00	11.571	18.365	4/14/2004	4:20:00	42.274	44.521
4/7/2004	4:20:00	14.473	17.452	4/14/2004	4:25:00	42.332	44.542
4/7/2004	4:25:00	12.744	19.815	4/14/2004	4:30:00	42.247	44.502
4/7/2004	4:30:00	9.095	18.394	4/14/2004	4:35:00	42.295	44.376
4/7/2004	4:35:00	9.656	15.388	4/14/2004	4:40:00	42.268	44.438
4/7/2004	4:40:00	12.864	15.934	4/14/2004	4:45:00	42.225	44.488
4/7/2004	4:45:00	12.429	18.64	4/14/2004	4:50:00	42.193	44.408
4/7/2004	4:50:00	9.62	18.055	4/14/2004	4:55:00	42.253	44.361
4/7/2004	4:55:00	9.063	15.85	4/14/2004	5:00:00	42.461	44.381
4/7/2004	5:00:00	10.455	15.379	4/14/2004	5:05:00	42.65	44.555
4/7/2004	5:05:00	9.437	16.438	4/14/2004	5:10:00	42.691	44.654
4/7/2004	5:10:00	9.85	15.749	4/14/2004	5:15:00	42.623	44.682
4/7/2004	5:15:00	9.853	15.994	4/14/2004	5:20:00	42.634	44.622
4/7/2004	5:20:00	8.68	15.952	4/14/2004	5:25:00	42.543	44.648
4/7/2004	5:25:00	8.03	14.938	4/14/2004	5:30:00	42.525	44.577
4/7/2004	5:30:00	9.744	14.301	4/14/2004	5:35:00	42.558	44.509
4/7/2004	5:35:00	9.506	15.966	4/14/2004	5:40:00	42.395	44.508
4/7/2004	5:40:00	7.393	15.632	4/14/2004	5:45:00	42.432	44.362
4/7/2004	5:45:00	6.905	13.724	4/14/2004	5:50:00	42.425	44.446
4/7/2004	5:50:00	6.867	12.679	4/14/2004	5:55:00	42.534	44.409
4/7/2004	5:55:00	7.669	12.876	4/14/2004	6:00:00	42.667	44.517
4/7/2004	6:00:00	7.036	14.026	4/14/2004	6:05:00	42.469	44.682
4/7/2004	6:05:00	6.39	13.834	4/14/2004	6:10:00	42.385	44.54
4/7/2004	6:10:00	6.766	12.673	4/14/2004	6:15:00	42.322	44.443
4/7/2004	6:15:00	7.091	13.328	4/14/2004	6:20:00	42.212	44.345
4/7/2004	6:20:00	5.834	13.673	4/14/2004	6:25:00	42.303	44.191
4/7/2004	6:25:00	5.218	12.028	4/14/2004	6:30:00	42.375	44.335
4/7/2004	6:30:00	5.801	11.505	4/14/2004	6:35:00	42.436	44.332
4/7/2004	6:35:00	5.717	12.153	4/14/2004	6:40:00	42.42	44.393
4/7/2004	6:40:00	5.966	12.07	4/14/2004	6:45:00	42.377	44.418

Electric Usage Records

After the Project				Before the Poject			
Record Date	Record End Time	Aerator 2012 Avg. kW	Aerator 2014 Avg. kW	Record Date	Record End Time	Aerator 2013 Avg. kW	Aerator 2011 Avg. kW
4/7/2004	6:45:00	5.592	12.506	4/14/2004	6:50:00	42.293	44.395
4/7/2004	6:50:00	4.989	11.835	4/14/2004	6:55:00	27.603	44.305
4/7/2004	6:55:00	4.747	11.229	4/14/2004	7:00:00	23.65	44.626
4/7/2004	7:00:00	5.06	11.066	4/14/2004	7:05:00	23.596	44.933
4/7/2004	7:05:00	5.165	11.263	4/14/2004	7:10:00	23.598	44.741
4/7/2004	7:10:00	5.103	11.477	4/14/2004	7:15:00	23.65	44.789
4/7/2004	7:15:00	4.338	11.339	4/14/2004	7:20:00	23.726	44.858
4/7/2004	7:20:00	3.674	10.365	4/14/2004	7:25:00	23.738	44.952
4/7/2004	7:25:00	4.275	9.447	4/14/2004	7:30:00	23.73	45.04
4/7/2004	7:30:00	4.745	10.369	4/14/2004	7:35:00	23.615	45.024
4/7/2004	7:35:00	4.327	10.887	4/14/2004	7:40:00	23.726	44.781
4/7/2004	7:40:00	3.988	10.439	4/14/2004	7:45:00	23.817	45.017
4/7/2004	7:45:00	3.736	10.012	4/14/2004	7:50:00	23.948	45.446
4/7/2004	7:50:00	3.543	9.76	4/14/2004	7:55:00	23.955	45.796
4/7/2004	7:55:00	3.377	9.453	4/14/2004	8:00:00	23.935	45.614
4/7/2004	8:00:00	3.792	9.234	4/14/2004	8:05:00	23.978	45.579
4/7/2004	8:05:00	4.184	9.669	4/14/2004	8:10:00	24.035	45.494
4/7/2004	8:10:00	4.124	10.25	4/14/2004	8:15:00	23.936	45.234
4/7/2004	8:15:00	3.147	10.23	4/14/2004	8:20:00	23.902	44.779
4/7/2004	8:20:00	2.799	8.882	4/14/2004	8:25:00	23.861	44.709
4/7/2004	8:25:00	3.523	8.478	4/14/2004	8:30:00	23.885	44.879
4/7/2004	8:30:00	4.079	9.42	4/14/2004	8:35:00	23.96	45.09
4/7/2004	8:35:00	4.02	10.175	4/14/2004	8:40:00	24.09	45.313
4/7/2004	8:40:00	3.146	10.006	4/14/2004	8:45:00	23.994	45.642
4/7/2004	8:45:00	2.749	8.826	4/14/2004	8:50:00	23.97	45.434
4/7/2004	8:50:00	3.515	8.266	4/14/2004	8:55:00	23.938	45.265
4/7/2004	8:55:00	4.082	9.369	4/14/2004	9:00:00	23.877	45.099
4/7/2004	9:00:00	4.112	10.175	4/14/2004	9:05:00	23.824	45.035
4/7/2004	9:05:00	3.336	10.192	4/14/2004	9:10:00	23.925	44.989
4/7/2004	9:10:00	3.3	9.182	4/14/2004	9:15:00	23.968	45.423
4/7/2004	9:15:00	4.36	9.171	4/14/2004	9:20:00	24	45.725
4/7/2004	9:20:00	4.44	10.617	4/14/2004	9:25:00	23.936	45.623
4/7/2004	9:25:00	3.666	10.787	4/14/2004	9:30:00	23.939	45.41
4/7/2004	9:30:00	4.063	9.721	4/14/2004	9:35:00	23.885	45.354
4/7/2004	9:35:00	4.078	10.35	4/14/2004	9:40:00	23.916	45.472
4/7/2004	9:40:00	4.559	10.38	4/14/2004	9:45:00	23.953	45.583
4/7/2004	9:45:00	5.348	11.09	4/14/2004	9:50:00	23.967	45.566
4/7/2004	9:50:00	5.964	11.849	4/14/2004	9:55:00	23.915	45.395
4/7/2004	9:55:00	5.587	12.578	4/14/2004	10:00:00	23.898	45.103
4/7/2004	10:00:00	5.793	12.26	4/14/2004	10:05:00	23.948	45.092
4/7/2004	10:05:00	6.567	12.476	4/14/2004	10:10:00	23.928	45.438
4/7/2004	10:10:00	6.304	12.849	4/14/2004	10:15:00	23.874	45.197
4/7/2004	10:15:00	6.037	12.734	4/14/2004	10:20:00	23.915	44.759
4/7/2004	10:20:00	6.45	12.784	4/14/2004	10:25:00	23.877	44.625
4/7/2004	10:25:00	7.225	13.185	4/14/2004	10:30:00	23.885	44.444
4/7/2004	10:30:00	8.22	14.204	4/14/2004	10:35:00	23.803	44.406

APPENDIX B, As-Built Drawing for VFD Control

MODEL NUMBER			NEMA 1 DIMENSIONS inches (mm)															
208V	460V	600V	H	W	D1	D2	a	b	c	d	e	f	g	h	j	k	l	m
VLT6000C4.6–11	VLT6000H2.1–14	VLT6000J1.7–11	30.40 (772)	24.85 (631)	8.59 (218)	10.63 (270)	23.35 (593)	0.75 (19)	28.03 (712)	1.64 (42)	16.14 (410)	7.50 (191)	1.75 (44)	4.00 (102)	6.50 (165)	4.50 (114)	1.50 (38)	12.00 (305)
VLT6000C17–59	VLT6000H21–52	VLT6000J17–41	41.28 (1048)	25.50 (648)	10.95 (278)	12.99 (330)	24.00 (610)	0.75 (19)	38.89 (989)	1.64 (42)	16.14 (410)	7.50 (191)	1.75 (44)	4.00 (102)	6.50 (165)	4.50 (114)	1.50 (38)	12.00 (305)
VLT6000C75–88	VLT6000H65–106	VLT6000J52–77	50.81 (1291)	33.41 (848)	12.36 (314)	14.41 (366)	31.61 (802)	0.90 (23)	48.35 (1228)	1.65 (42)	21.36 (543)	12.00 (305)	1.75 (44)	4.00 (102)	7.00 (178)	4.50 (114)	1.50 (38)	15.00 (381)



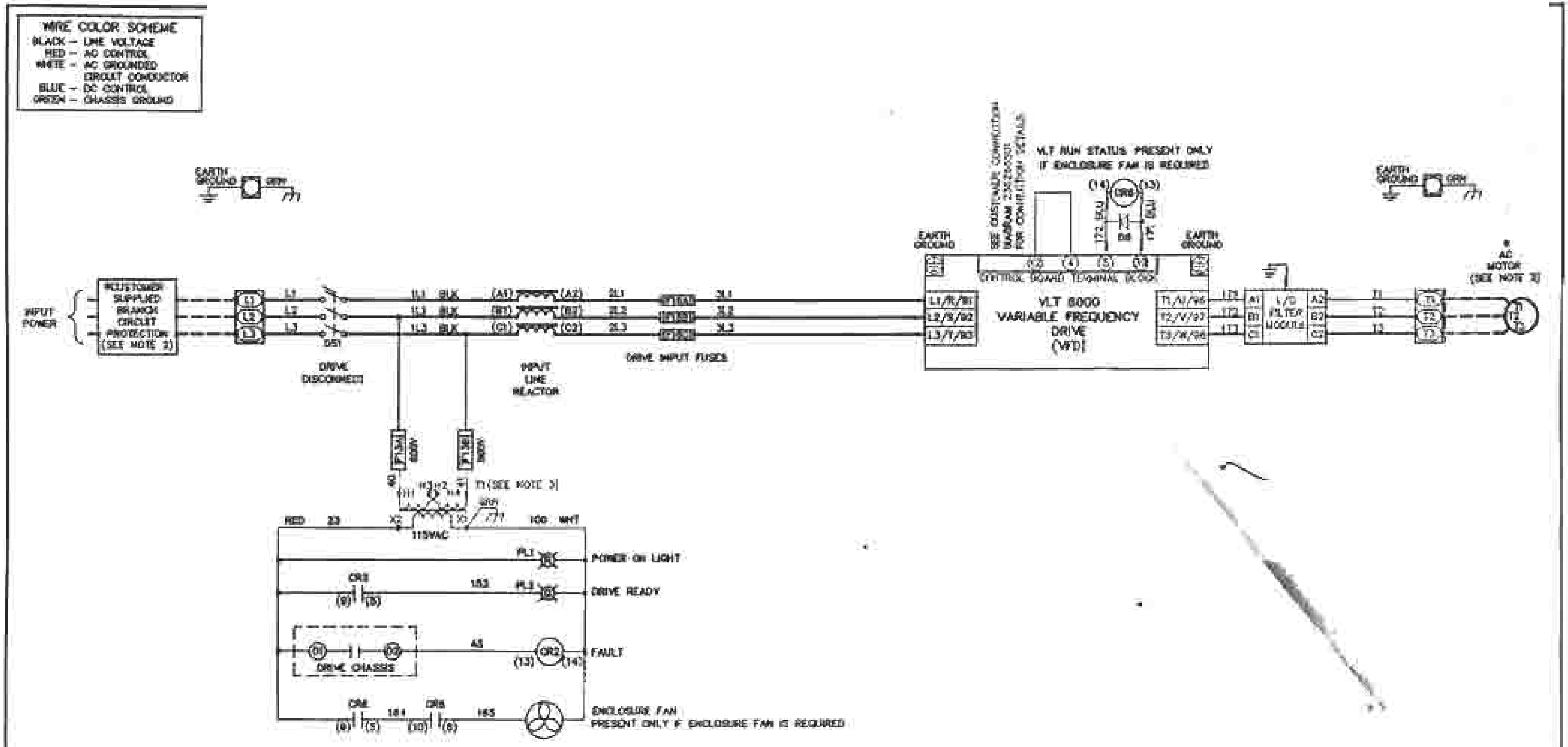
REV	ECN	DATE
B		
A		
DR	20010535	12/01

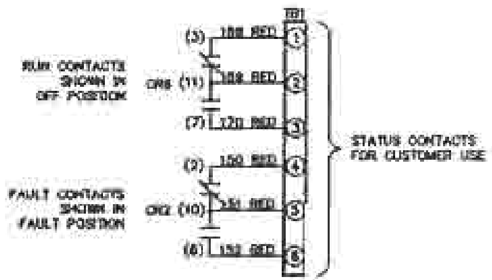
DRN GS 1/02
APR 11/02 RHW

NAME INSTALLATION DRAWING
DRIVE W/ AUX. ENCL. NEMA 1 / NEMA 12

Danfoss

MODEL VLT6000 | PAGE 1 OF 2 | SIZE A | DWG NO. 176U7603





NOTES:
1. * INDICATES COMPONENTS NOT SUPPLIED BY FACTORY.
2. BRANCH CIRCUIT PROTECTION, INPUT POWER AND MOTOR WIRING MUST BE SELECTED IN ACCORDANCE WITH THE N.E.C., ANY APPLICABLE LOCAL CODES AND THE DRIVE CURRENT RATING.
3. T1 IS SHOWN CONNECTED FOR 480VAC INPUT. SEE DRAWING 175U7441 FOR TRANSFORMER USAGE AND CONNECTIONS FOR INPUT VOLTAGES OTHER THAN 480VAC.

REV	ECN	DATE
B		
A		
DR	20030541	8/03

— NOTICE —

DRN 8-19-03
APR 8-21-03

NAME: SCHEMATIC DIAGRAM STANDARD DRIVE W/ DRIVE DISC. & INPUT FUSES

MODEL: VLT

PAGE 1 OF 1

SIZE A

DWG NO. 236266S02

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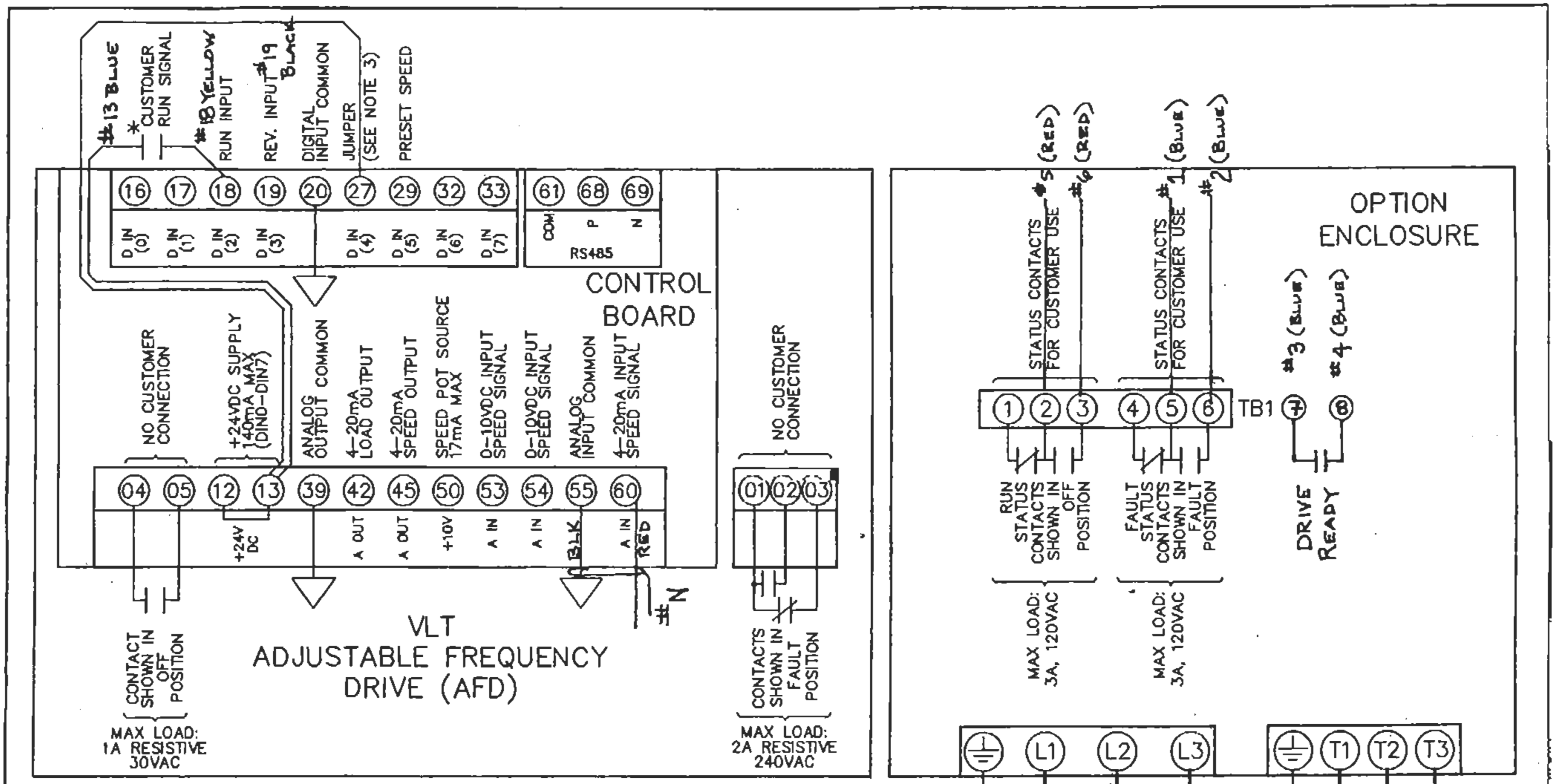

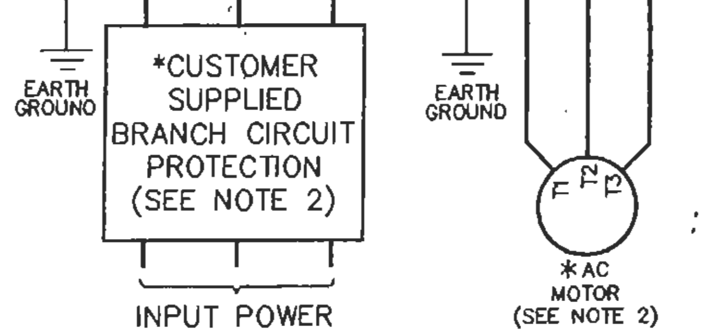

NOTES:
1.) * INDICATES COMPONENTS NOT SUPPLIED BY FACTORY.
2.) BRANCH CIRCUIT PROTECTION AND WIRE SIZE MUST BE SELECTED IN ACCORDANCE WITH THE N.E.C., ANY APPLICABLE LOCAL CODES AND THE DRIVE'S CURRENT RATING.
3.) REPLACE JUMPER WITH N.C. SAFETY INTERLOCK CONTACT AS NECESSARY.

REV	ECN	DATE
B		
A		
DR	20030541	8/03

DRN 8-15-03
APR 8-21-03

NAME CUSTOMER CONNECTION DIAGRAM STANDARD DRIVE WITH OPTION ENCLOSURE

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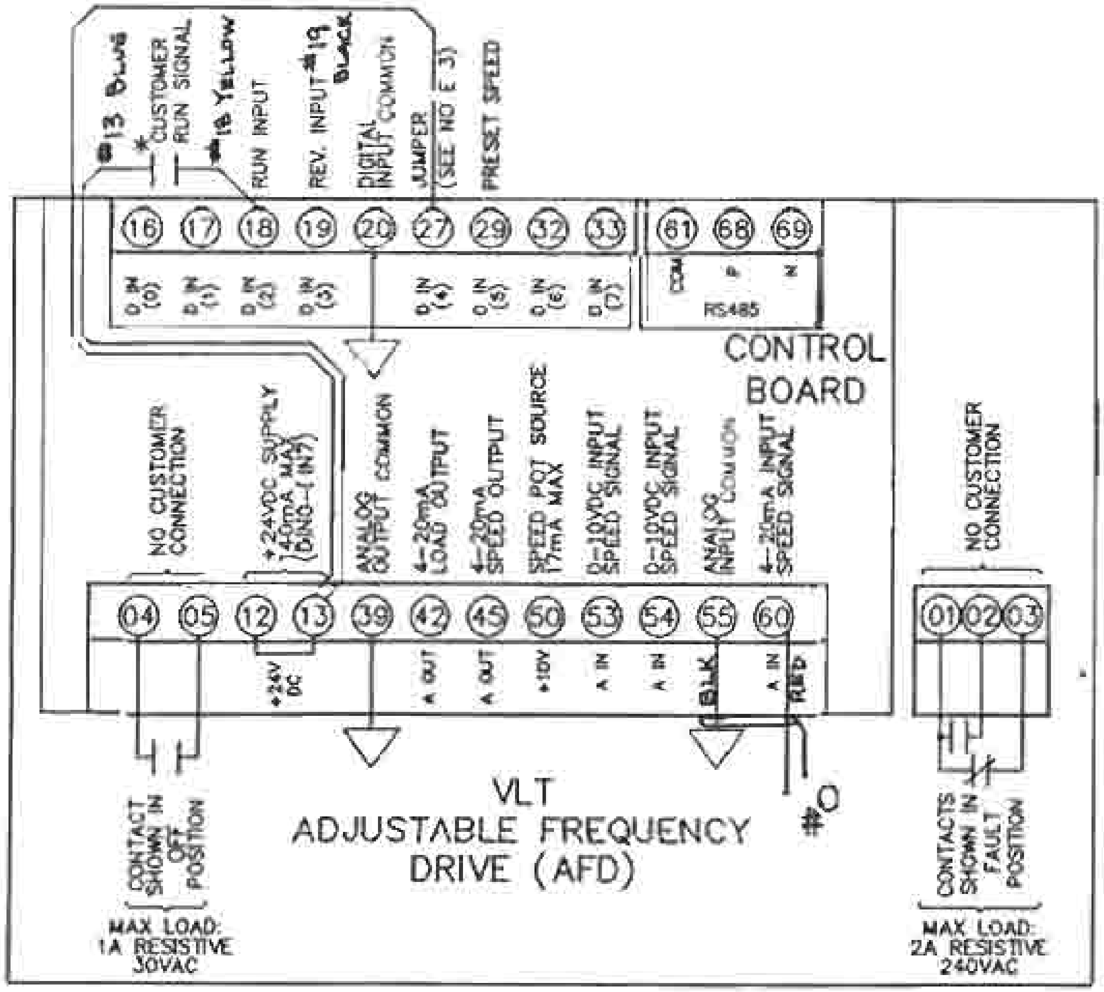
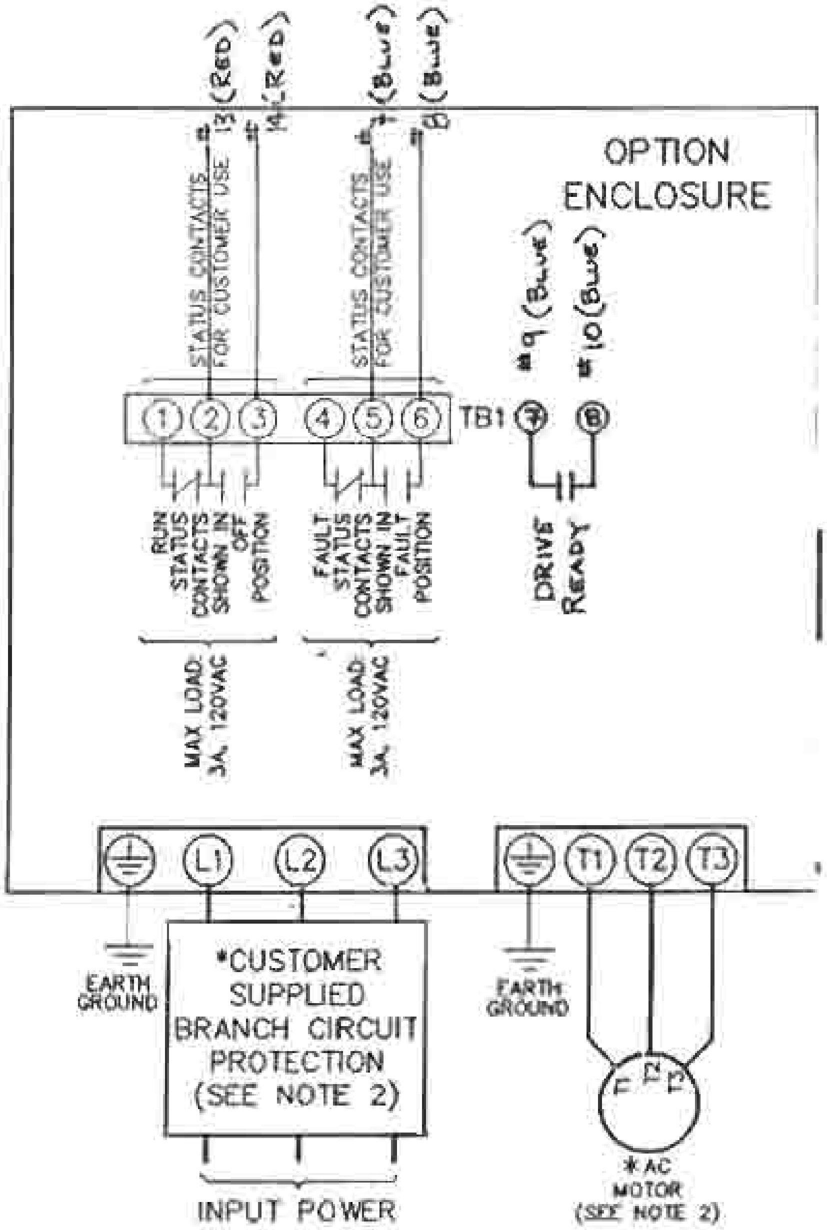
MODEL VLT | PAGE 1 OF 1 | SIZE A | DWG NO. 236266S01

AERATOR 2012





NOTES:

1.) * INDICATES COMPONENTS NOT SUPPLIED BY FACTORY.

2.) BRANCH CIRCUIT PROTECTION AND WIRE SIZE MUST BE SELECTED IN ACCORDANCE WITH THE N.E.C., ANY APPLICABLE LOCAL CODES AND THE DRIVE'S CURRENT RATING.

3.) REPLACE JUMPER WITH N.C. SAFETY INTERLOCK CONTACT AS NECESSARY.

B		
A		
DR	20030541	8/03
REV	ECN	DATE

DRN 8-15-03

APR 8-21-03

NAME: CUSTOMER CONNECTION DIAGRAM STANDARD DRIVE WITH OPTION ENCLOSURE

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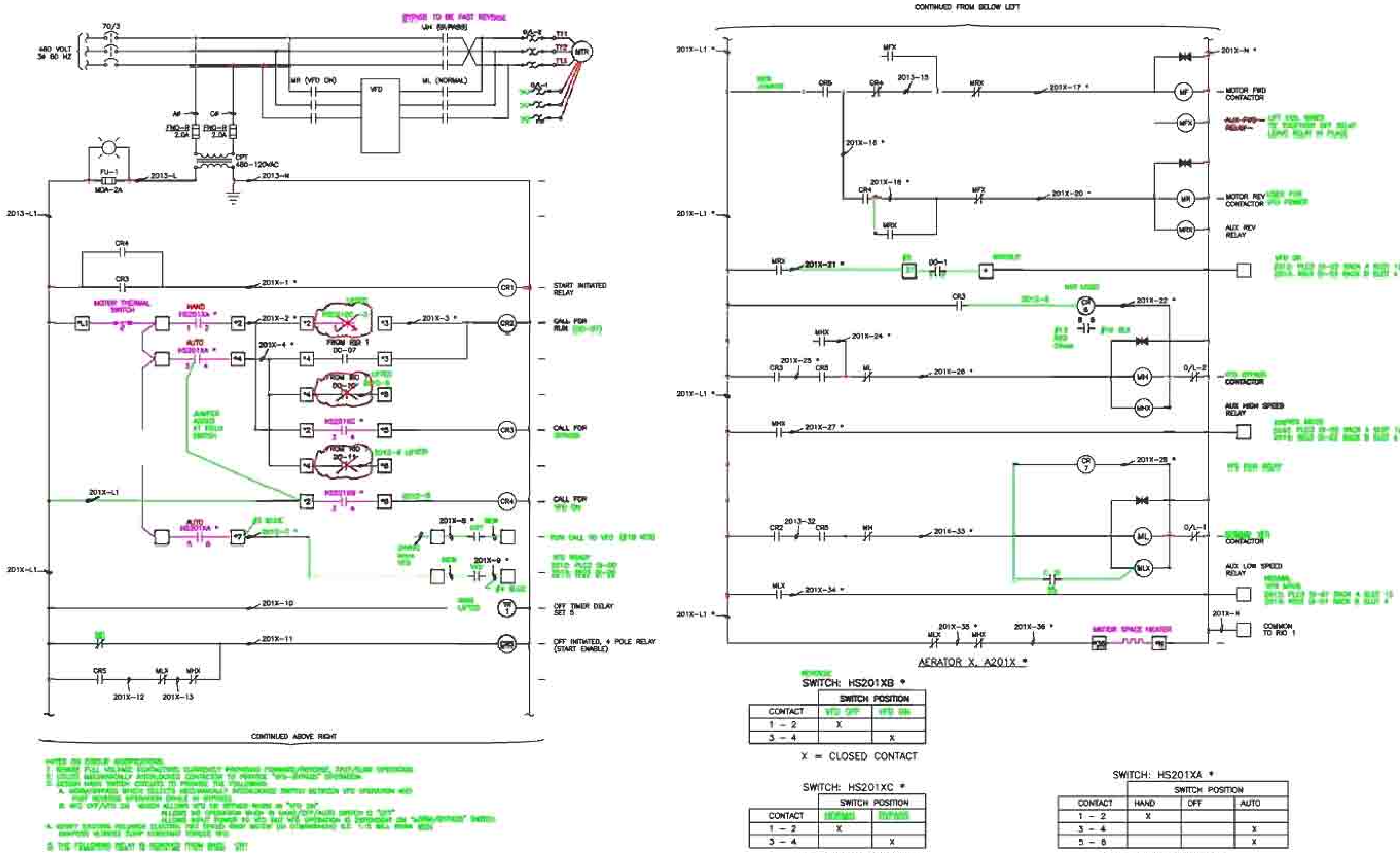
MODEL VLT | PAGE 1 OF 1 | SIZE A | DWG NO. 236266S01

AERATOR 2014



SWITCH: HS201XB *

CONTACT	SWITCH POSITION	
1 - 2	X	
3 - 4		X

X = CLOSED CONTACT

SWITCH: HS201XC *

CONTACT	SWITCH POSITION	
1 - 2	X	
3 - 4		X

X = CLOSED CONTACT

SWITCH: HS201XA *

CONTACT	SWITCH POSITION		
	HAND	OFF	AUTO
1 - 2	X		
3 - 4			X
5 - 6			X

X = CLOSED CONTACT

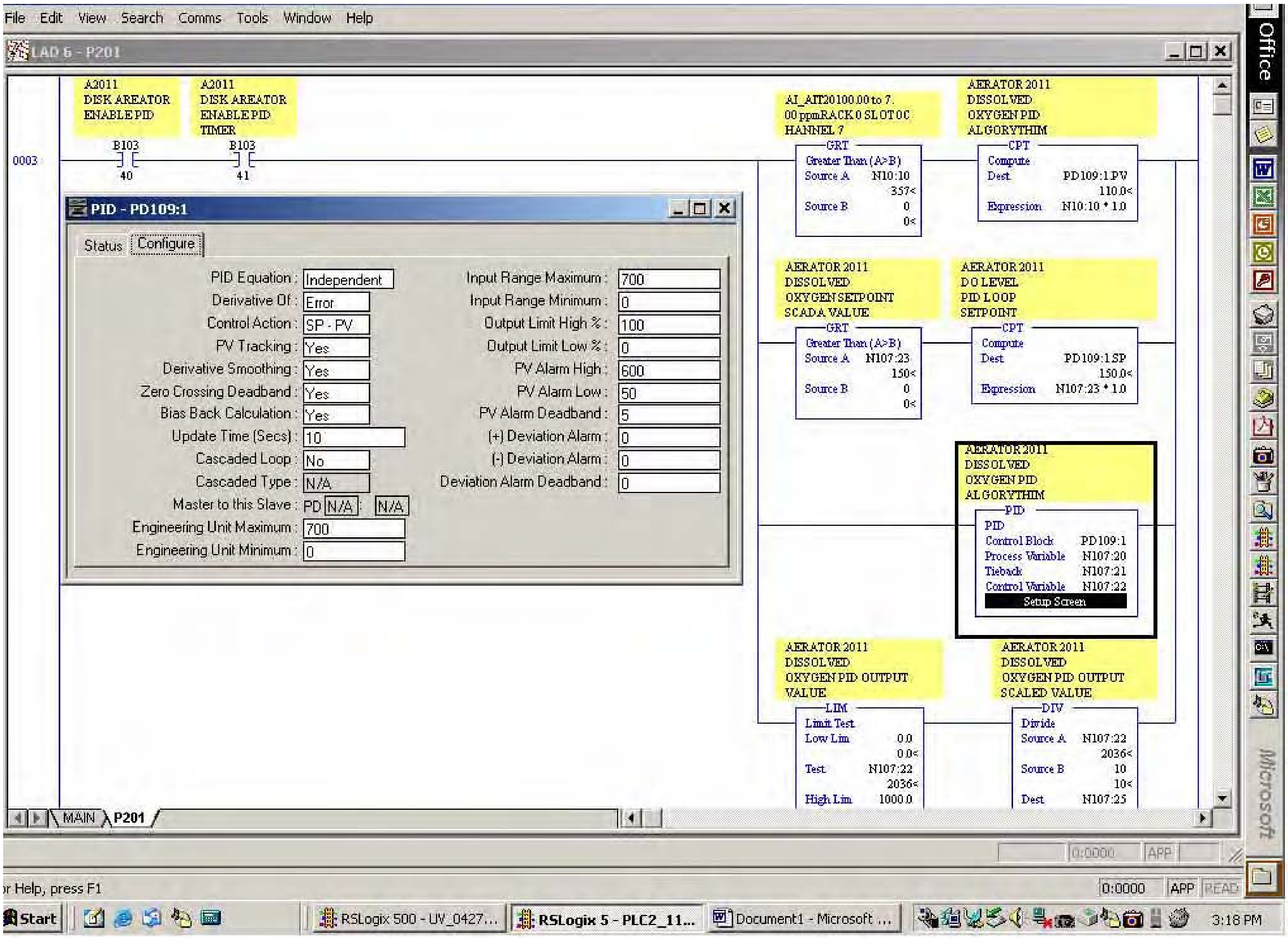
* = 201X = 2012 AND 2014

REV	DATE	BY	DESCRIPTION
1	10/1/03	MSW	ISSUED FOR CONSTRUCTION

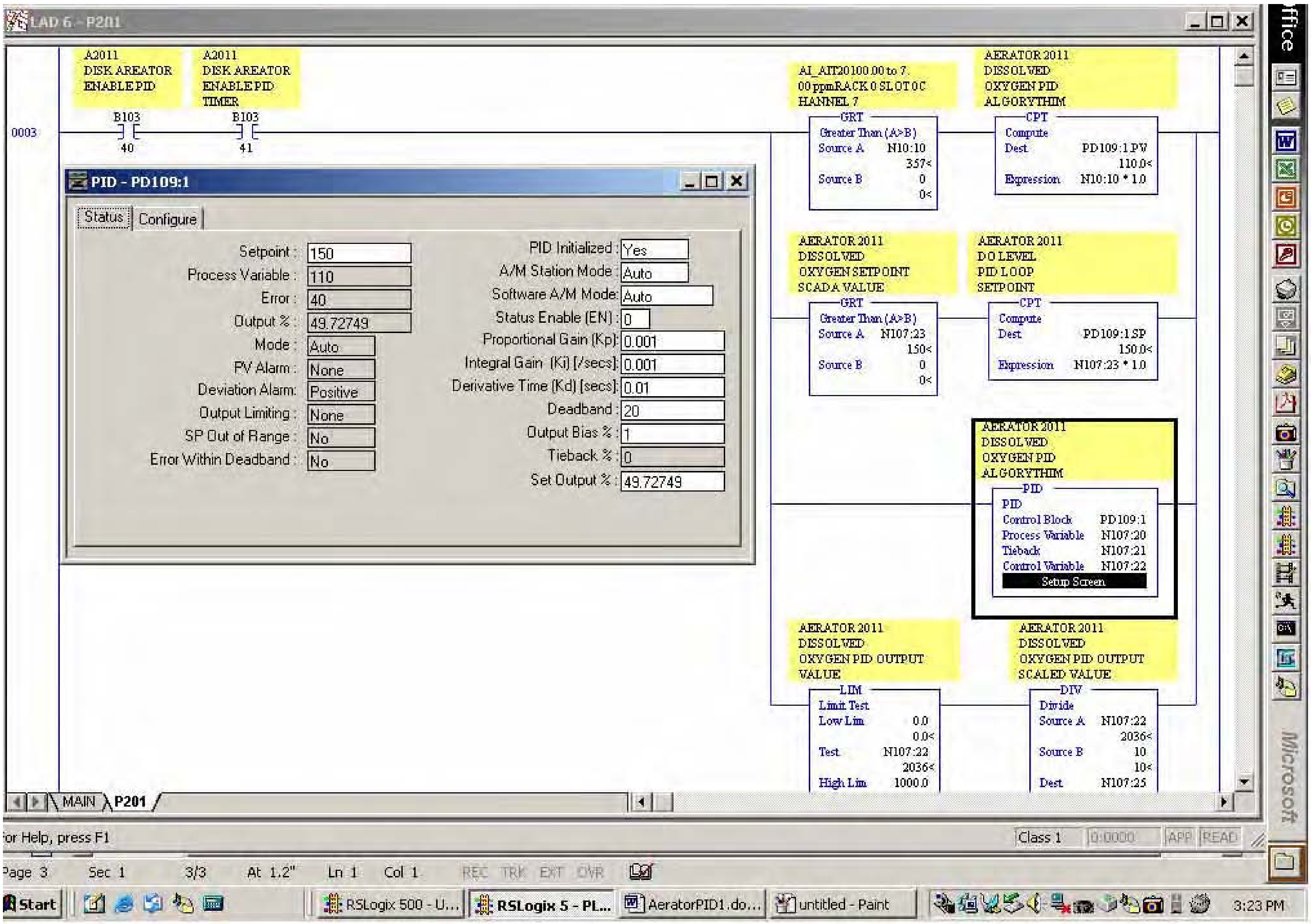
UC DAVIS WASTEWATER TREATMENT PLANT
AERATOR X *
CONTROL SCHEMATICS

DATE	DESIGN BY	DRAWN BY	CHK'D BY	SHEET #	DRAWING #
10/20/03	SRJ	SLV		NEW OF -	21082247

APPENDIX C, PLC Programming


File Edit View Search Comms Tools Window Help
LAD 6 - P201
A2011 DISK AREATOR ENABLE PID
A2011 DISK AREATOR ENABLE PID TIMER
B103 40
B103 41
0003
AI_AIT20100.00 to 7.00 ppmRACK 0 SLOT 0 CHANNEL 7
GRT Greater Than (A>B) Source A N10:10 357< Source B 0 0<
AERATOR 2011 DISSOLVED OXYGEN PID ALGORYTHIM
CPT Compute Dest PD109:1.PV 110.0< Expression N10:10 * 1.0
AERATOR 2011 DISSOLVED OXYGEN SETPOINT SCADA VALUE
GRT Greater Than (A>B) Source A N107:23 150< Source B 0 0<
AERATOR 2011 DO LEVEL PID LOOP SETPOINT
CPT Compute Dest PD109:1.SP 150.0< Expression N107:23 * 1.0
AERATOR 2011 DISSOLVED OXYGEN PID ALGORYTHIM
PID PID Control Block PD109:1 Process Variable N107:20 Tieback N107:21 Control Variable N107:22 Setup Screen
AERATOR 2011 DISSOLVED OXYGEN PID OUTPUT VALUE
LIM Limit Test Low Lim 0.0 0.0< Test N107:22 2036< High Lim 1000.0
AERATOR 2011 DISSOLVED OXYGEN PID OUTPUT SCALED VALUE
DIV Divide Source A N107:22 2036< Source B 10 10< Dest N107:25
PID - PD109:1
Status Configure
PID Equation : Independent
Derivative Of : Error
Control Action : SP - PV
PV Tracking : Yes
Derivative Smoothing : Yes
Zero Crossing Deadband : Yes
Bias Back Calculation : Yes
Update Time (Secs) : 10
Cascaded Loop : No
Cascaded Type : N/A
Master to this Slave : PD N/A : N/A
Engineering Unit Maximum : 700
Engineering Unit Minimum : 0
Input Range Maximum : 700
Input Range Minimum : 0
Output Limit High % : 100
Output Limit Low % : 0
PV Alarm High : 600
PV Alarm Low : 50
PV Alarm Deadband : 5
(+) Deviation Alarm : 0
(-) Deviation Alarm : 0
Deviation Alarm Deadband : 0
MAIN P201
0:0000 APP
r Help, press F1
0:0000 APP READ
Start
RSLogix 500 - UV_0427...
RSLogix 5 - PLC2_11...
Document1 - Microsoft ...
3:18 PM
Office
Microsoft

R


LAD 6 - P201
A2011 DISK AREATOR ENABLE PID
A2011 DISK AREATOR ENABLE PID TIMER
B103 40
B103 41
0003
PID - PD109:1
Status
Configure
Setpoint : 150
Process Variable : 110
Error : 40
Output % : 49.72749
Mode : Auto
PV Alarm : None
Deviation Alarm: Positive
Output Limiting : None
SP Out of Range : No
Error Within Deadband : No
PID Initialized : Yes
A/M Station Mode : Auto
Software A/M Mode: Auto
Status Enable (EN) : 0
Proportional Gain (Kp): 0.001
Integral Gain (Ki) [/secs]: 0.001
Derivative Time (Kd) [secs]: 0.01
Deadband : 20
Output Bias % : 1
Tieback % : 0
Set Output % : 49.72749
AI_AIT20100.00 to 7.00ppmRACK 0 SLOT 0 CHANNEL 7
GRT
Greater Than (A>B)
Source A N10:10 357<
Source B 0 0<
AERATOR 2011 DISSOLVED OXYGEN PID ALGORYTHIM
CPT
Compute
Dest PD109:1.PV 110.0<
Expression N10:10 * 1.0
AERATOR 2011 DISSOLVED OXYGEN SETPOINT SCADA VALUE
GRT
Greater Than (A>B)
Source A N107:23 150<
Source B 0 0<
AERATOR 2011 DO LEVEL PID LOOP SETPOINT
CPT
Compute
Dest PD109:1.SP 150.0<
Expression N107:23 * 1.0
AERATOR 2011 DISSOLVED OXYGEN PID ALGORYTHIM
PID
PID
Control Block PD109:1
Process Variable N107:20
Tieback N107:21
Control Variable N107:22
Setup Screen
AERATOR 2011 DISSOLVED OXYGEN PID OUTPUT VALUE
LIM
Limit Test
Low Lim 0.0 0.0<
Test N107:22 2036<
High Lim 1000.0
AERATOR 2011 DISSOLVED OXYGEN PID OUTPUT SCALED VALUE
DIV
Divide
Source A N107:22 2036<
Source B 10 10<
Dest N107:25
MAIN
P201
For Help, press F1
Class 1
Page 3 Sec 1 3/3 At 1.2" Ln 1 Col 1 REC TRK EXT OVR
Start
RSLogix 500 - U...
RSLogix 5 - PL...
AeratorPID1.do...
untitled - Paint
3:23 PM
Microsoft Office